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THE GAS JOURNAL

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EDITORIAL NOTES

Well Worth While.

Now we are looking forward to some real optimism from the leaders and from the rank and file of the research workers in our industry, for both Mr. Shapley and Mr. Copp have given them full opportunity to exploit their virtues and their talents. In the November of 1929, and again a week ago, they were enabled to hold their own fort and the interest of the Institution of Gas Engineers. Let it be said at once that they have held it on both occasions very nobly indeed, and that, thanks to a slight development of the histrionic sense, this Year of Grace wins. Of course, there was plenty of background for this year's autumnal meeting—panelled walls and the confidence created by former prowess. But it was not to these influences alone that the meeting of the Institution of Gas Engineers owed its success; it was due to the increasing appreciation that workers in the laboratory of a university, or university workers in the field of industry, do in fact realize and understand the viewpoint of those responsible for balance-sheets. At present, we make bold to say, the balance-sheet experts demonstrate more obstinacy than do the research workers; and it is significant that, the more the balance shows a tendency towards a deficit, the more do the research people come into prominence.

At all events, the chemical investigators had a thoroughly good time at the palatial premises of the Incorporated Accountants last week; their remarks and their reports were well received, and they have nothing whatever to grumble about. At times it seemed, indeed, as though the umbrella of sentimentalism was shielding them from the bitter blows of commercial realism. To-day research workers ought to be not only grateful, but happy. Certainly the gas industry is happy about them. They have done, and are accomplishing, sterling work in a crystal field of many facets.

All manner of interesting, absorbing things emerged from the meeting last week—a meeting to which the "JOURNAL" devotes itself almost exclusively to-day. And it is to one or two of these interesting things that we desire to call attention in this brief article on a very august gathering. First and foremost, we wish to mention that the gas industry of a few years' time may not rely solely on the virtues of radiant heat. Radiant heat is highly excellent, but all its virtues will not belie the advantages of convection in certain circumstances. The sooner our industry views in proper perspective the problem of carbon monoxide and adequate ventilation, the better. For years we have been hounded from pillar to post on this question of carbon monoxide; and we have been afraid to recognize the facts and to design healthy and efficient flueless heaters. But it may be that in the next few years we shall both design efficient convection heaters and shall have the courage to sell them. This is one of the ideas that emerges from the research work discussed on the Tuesday and Wednesday of last week.

This idea, of course, is only one of many; but it indicates the essential practical nature of the major portion of the reports presented and the discussions which they evoked. There may be some who will think that the Gas Fellowship Report is not exactly thrilling. The findings expressed therein are "fundamental"—a word which covers a multitude of virtues and vices—and there may be those who think that in present circumstances "fundamentals" might temporarily give way to something less fundamental, but more in keeping with current conditions.

One too often hears the hackneyed expression, "inferiority complex." On several occasions during the discussions, it was made manifest that we as an industry do not always act as a powerful organization should—an organization essentially honest, which pays its dividends with unfailing regularity, which is able to raise capital easily, and which has such amazing possibilities. The remarks of Mr. Parrish, for example, were more than opportune; and he deserves praise for his pluck, just as he deserves praise for his scientific ingenuity. Maybe his views will not invariably find full support, as is suggested by his observations in regard to the ammonium sulphate situation in Germany; but at least he has the courage of his convictions, and he is definitely stimulating current thought on the difficulties which the gas industry has to face. He preaches a "superiority complex" doctrine for the gas industry; so does Dr. E. W. Smith, and so do we. And we believe firmly that in the future the gas industry will win abundant prosperity through one channel alone—that of co-operative strength.

The foregoing indicates the type of reflections which the admirable meeting of the Institution last week calls forth. To leave the scientific, for a moment, for the ordinary, we have much for which to be grateful to the organizers of what we consider to be one of the best and most fruitful gas research meetings ever held in this country. First of all, we have now arrived at the stage when research reports are to all intents and purposes taken as read. This practice is both belated and excellent; and as other senior institutions have proved, it gives rise to the exploitation of the *raison d'être* of such reports—discussion. As the columns of this issue of the "JOURNAL" testify, the discussions this year were both thorough and productive. Admittedly, however, these discussions would have been still more productive had the reports been issued to members a few days instead of a few hours before presentation.

Another feature which strengthened and consolidated the discussions was the real benefit derived from the fact that there was an omnibus vote of thanks. We are not so childish to-day as not to understand that professors, research workers, scrutineers, individual undertakings, secretaries, and divers staffs are worth their salt. Of course, they are; and all good luck to the brave man who suggested that they should be thanked for their services in an omnibus resolution. We repeat, this year's autumnal research meeting of the Institution proved most successful.

OBITUARY

HENRY WOODALL.

On the eve of going to press with this special number of the "JOURNAL," containing a report of the whole of the proceedings at last week's Autumn Research Meeting of an Institution which he loved so well, and among the members of which he was so universally respected, comes news of the death, at Aberystwyth, on Nov. 30, of Mr. Henry Woodall, probably the oldest gas engineer, at the ripe age of 92.

As recently as two years ago, at a meeting of the Institution of Gas Engineers, called in connection with an application for a Royal Charter which has since been granted, Mr. Woodall made a speech full of life and sparkle, in which he recalled some of the early incidents of a long career devoted to the gas industry. He was a founder member of the British Association of Gas Managers, which was formed in 1863, and which in 1881 became the Gas Institute. In that year he made up his mind to become President of that organization, and to manufacture the cheapest gas in Great Britain; and he mentioned at the meeting referred to, that he had accomplished both purposes.

Deceased was born at Wolverhampton in 1839, at which date his father was Manager of the Gas-Works there. At the age of 14 he entered the service of the Liverpool Gas Company, with whom he served an apprenticeship of seven years, after which he removed to Burslem, and served another three years with his brother, Mr. William Woodall. He was then appointed Manager of the Longton Gas Company, and held the appointment for about three years. Here he commenced negotiations for the purchase of the business of the Stoke, Fenton, and Longton Gas Company, with whom his Company was in competition. His next move was to Burslem, where he succeeded his brother as Engineer and Secretary, and where he continued in office for more than ten years. In 1875, Mr. Woodall was appointed Engineer and Manager of the Leeds Corporation Gas-Works. In 1886 he went out to Melbourne, and subsequently became Consulting Engineer to the Metropolitan Gas Company there.

Mr. Woodall became President of the Gas Institute, and was a member of the Manchester District Institution of Gas Engineers, of which he became President in 1883. He was also a member of the North of England Gas Managers' Association, being President in the year 1885. In addition he was elected President of an Association which was intended to cover North Wales, but which project fell through from lack of support.

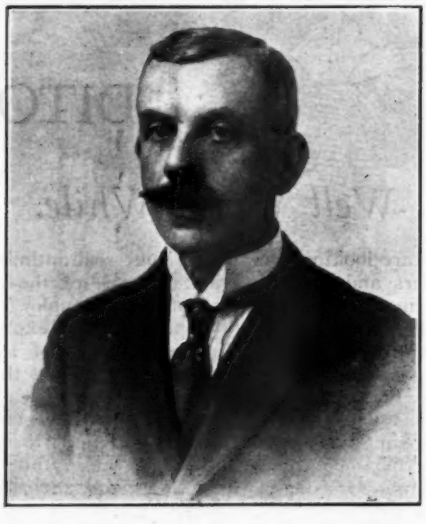
At the last annual meeting of the British Commercial Gas Association, the President, Mr. Henry Woodall, said: "Complaint has been made as to the age of directors of companies. We all recognize that experience is needed as well as imagination and enthusiasm. But may I be allowed to mention that at the beginning of this month I spent a few days with, I believe, the oldest living gas Engineer and Director—my uncle, Mr. Henry Woodall. He is now 92, and is Chairman of one of the best managed gas companies in the kingdom; he is not Chairman in name only, and no one even now could with impunity cross swords with him on any matter connected with the gas industry. I am proud, as also are many of you, to have worked with him, and we recognize that age cannot wither nor custom stale his infinite variety."

Mr. Woodall's life-long activity with gas undertakings embraced Chairmanship of the Aberystwyth Gas Company (of which he became Managing Director in 1903), and Directorships of the Ascot District Gas and Electricity Company and the former Waltham and Cheshunt Gas Company.

The funeral took place at Llanrhôs yesterday.

J. A. MACLEOD.

The death has occurred, after a short illness, of Mr. John Andrew Macleod, Director of Parkinson & Cowan, Ltd. Mr. Macleod was associated with the Company and its predecessors



in business for over fifty years, and during the whole of that period his outstanding abilities and personality won the affectionate esteem of his colleagues, who feel that to them his loss is irreparable.

The death occurred, on Nov. 26, of Mr. Walter Grange, Managing Director of Messrs. Foster & Pullen, Ltd., Brass Founders and Engineers, of Fairweather Green, Bradford. Mr. Grange was to have been the lecturer to the West Riding of Yorkshire Gas Salesmen's Circle on Nov. 12, following a visit in the afternoon to Messrs. Foster & Pullen's works. The visit took place, but owing to the illness of Mr. Grange, his place in the evening had to be filled by Mr. R. E. Meadows, of Leeds. Mr. Grange had been connected with the firm throughout its career; he was a Fellow of the Chartered Institute of Secretaries, a keen member of the Bradford Circle for Foreign Languages and lecturer in Spanish, and well-known to the gas industry as a specialist in street lighting engineering.

PERSONAL

Mr. C. M. LAWSON, Chairman of the Girvan Gas Company, Ltd., who has been a member of the Girvan Town Council for eleven years, has been elected Provost of the Burgh.

Mr. A. MORRIS STICKELS, Technical Assistant to the Isle of Thanet Gas Company, Margate, left for Brazil on Saturday, Nov. 29, to take up an appointment at the Santos and Rio de Janeiro Gas-Works, under Mr. Bernard Browne. Mr. Stickels has been the recipient of a number of gifts, including a presentation from the Directors, the officials, staff, and the Sports Club of the Gas-Works at Margate.

Correspondence.

Gas Units.

SIR,—Should the effort not be towards a standardized gas sold quantitatively as of yore—*i.e.*, in cubic feet?

What do the gas appliance makers think on this matter? A gas burner, a gas fire, a gas cooker, built for (say) London gas, would then need no adjustment for other towns and cities.

"PRACTICE *v.* THEORY."

Nov. 29, 1930.

Our Institution Number.

The space demanded for the proper presentation in one issue of the valuable reports and discussions at last week's Autumn Research Meeting of the Institution of Gas Engineers has necessitated the holding over of a number of topical items which would otherwise have found space in this number of the "JOURNAL." Among these is the report of the meeting of the North of England Gas Managers' Association (Auxiliary Section) last Saturday, the continuation of the Magisterial proceedings in connection with the Nottingham conspiracy charges, and a report arising out of an inquiry under the Merchandise Marks Act.

THE NEWS OF THE WEEK

The Failure of the Electric Light on Saturday last placed the town of Alcester in partial darkness for several hours. The tradespeople and residents who had retained gas remained unaffected, but considerable inconvenience was caused in hotels and other business premises in which electricity had been installed.

A Gas Engineer and Manager is required (as will be seen from our advertisement columns) for the county borough of Blackpool. The commencing salary offered is £800 per annum, rising by annual increments of £50 to a maximum of £950 per annum. Applicants must be between 30 and 45 years of age. Forms of application can be obtained from the Town Clerk.

The Tenders for the £90,000 5 p.ct. redeemable debenture stock of the York Gas Company which was issued on behalf of the Directors of this Company were opened on Nov. 25. They amounted to a total of £367,120, and ranged from £102 down to the minimum of £97 per £100, the lowest successful tender being at £99 1s. 6d. p.ct., and the average price £99 6s. 6d. p.ct.

The Tenders for the £25,000 5½ p.ct. perpetual debenture stock which were offered on behalf of the Directors of the Tunbridge Wells Gas Company were opened on Dec. 1. They amounted to a total of £89,350 and ranged from £110 10s. 6d. down to the minimum of £105 per £100. The lowest accepted tender was £106 12s. 6d. p.ct., and the average price obtained for the whole of the issue was £107 3s. 3d. per £100.

A Commemoration Service to the 386 co-partners of the South Metropolitan Gas Company who lost their lives in the war will be held at Southwark Cathedral on Dec. 6. During the war, 3744 employees of this one Company joined the colours, and, in addition to those killed, more than 1000 were wounded. At the outset of hostilities the South Metropolitan Gas Company gave a lead to other large industrial firms by announcing that any employees joining the colours would be reinstated on their return from the war.

Winchester Stock Issue.—The Winchester Water and Gas Company are making an issue by tender of £20,000 5 p.ct. irredeemable preference stock at a minimum price of issue of £97 per £100 stock, ranking *pari passu* with the existing preference stock of the Company. The Directors are prepared to receive applications for the stock in amounts of £10 or multiples thereof. Tenders must be received at the Registered Office of the Company (90, High Street, Winchester), not later than 12 noon on Monday, Dec. 15, 1930.

The Illuminating Engineering Society, states the "Financial Times," have been registered as a Company, limited by guarantee, without share capital, with 500 members each liable for £1 in the event of winding up, to promote the general advancement of illuminating engineering. The management is vested in a Council, the first members of which include: Lieut.-Col. K. Edgcumbe (President), Sir Francis Goodenough (Vice-President), H. T. Harrison, C. W. Sully, J. W. Ife, A. W. Beuttell (of A. W. Beuttell, Ltd.), L. E. Buckell (General Electric Company), H. C. Bucklev (National Physical Laboratory, Teddington), G. Campbell (Benjamin Electric, Ltd.), P. Good (British Engineering Standards Association), E. L. Oughton (South Suburban Gas Company), F. W. Purse (London and Home Counties Joint Electricity Authority), and J. Terrace (South Suburban Gas Company). Registered office: 32, Victoria Street, Westminster, S.W. 1.

"Faith in Gas."—Such was the heading of a paragraph in last Saturday's "Grimsby Daily Telegraph" reporting the previous day's sale of new ordinary stock in the Cleethorpes Gas Company. The issue, amounting to £7900 with premiums, was readily taken up, mainly by local investors, and realized as high as £121 for £100 stock. This is in spite of greatly intensified electrical competition in the Company's area. The standard rate of dividend is 5 p.ct., subject to sliding scale. The interim dividend on this class of stock distributed for the half-year ended June 30, 1930, was at the rate of £7 15s. p.ct. per annum. Cleethorpes, as a seaside resort, has had in 1930 the worst season since the war, but the sales of gas show an increase over 1929, which was a record year. In order to meet prospective demands the Company is now having erected a 1½-million c.ft. capacity waterless gasholder (M.A.N. type), the contractors being Messrs. Robert Dempster & Sons, Ltd., of Elland.

An Interesting Situation has arisen at Blackburn in connection with the appointment of Corporation Committees. Last year Labour came into power for the first time in history, and Alderman E. Hamer, J.P., Liberal Leader, was deposed from his Aldermanship and Chairmanship of the Gas Committee, a position he had filled many years. Councillor H. Johnson was elected the first Labour Chairman of this Committee, with Mr. J. Holden (Conservative) as Vice-Chairman. On Nov. 25, the position was exactly reversed with the return to power of the Conservatives to the Council. Mr. J. Holden was appointed Chairman of the Gas Committee and Mr. H. Johnson the Vice-Chairman.

Nearly 40,000 Tons of Soot and Dirt are deposited every year on the surface of the City of London. This fact is revealed by Sir Hubert Llewellyn Smith, formerly Chief Economic Adviser to the British Government, in a plea for the more general use of smokeless fuel, which he makes in his newly-published survey, "London Life and Labour." Sir Hubert declares that, while the amount of atmospheric pollution is gradually declining, thanks largely to the increased use of gas and other smokeless fuels, it is impossible to rest satisfied with the present situation. It is the poorer people who suffer most, he states, as the incidence of the deposit is greatest in the most congested areas.

Owing to the Continued Growth of the Chelmsford Gas Undertaking the Gas Engineer has reported that it is necessary, in addition to enlarging the mains and distribution system, to embark on a progressive policy of works extension. The undertaking was purchased in 1917, and since then the production of gas has increased by 78 p.ct., and it is likely to continue to increase. In his opinion, it is necessary to commence forthwith upon a programme of rebuilding which, should the increase remain normal, will be spread over two or three years, and which will eventually entail capital expenditure amounting to approximately £16,000. The Committee have carefully considered the proposals outlined in the Engineer's report, and are of opinion that the time has now arrived when the question of the extension and replacement of the plant at the gas-works should receive immediate consideration, and therefore recommend that the Gas Engineer be instructed to submit a scheme and estimate of the cost of an extension to the retort house to the next meeting of the Committee, this being the first and most urgent portion of the scheme outlined in his report.

The Lighting of Glasgow.

Mr. S. B. Langlands, Lighting Inspector to the City of Glasgow, in the course of his report on the work of the Lighting Department of the Glasgow Corporation for two years ended May 31, 1930, states that the additional length of streets lighted in the city during the period was 46 miles—18 miles in 1928-29 and 28 in 1929-30—and the net number of public street lamps added during 1928-29 was 947, and during 1929-30 1733, or a total for the two years of 2680. The total of public street lamps thus reached at May 31, 1930, was 33,844. There were also at that date 151 private lamps under the charge of the Department, so that the grand total of street lamps, public and private, was 33,995.

During 1928-29 445 2·8 c.ft. burners were changed to 6·75 c.ft. burners, during 1929-30 556, during the two years 1001. On tramway routes, 'bus routes, at street junctions, and generally where more light is needed and where the introduction of large lamps must be delayed, improvement has been made and continues to be made by the substitution of four-mantle burners instead of the normal one-mantle burner. The standard type of lantern is retained; but usually the horizontal or roof burner is installed, giving rather higher efficiency than the swan-neck and a better appearance to the lantern. This change involves an increase per lamp from 2·8 c.ft. consumption of gas per hour to 6·75 c.ft. This change of consumption which took place in 1001 lamps, would represent a total increased consumption of gas per annum of nearly 14¾ million c.ft. The total consumption of gas during the year 1929-30 amounted to 474,409,579 c.ft. Under the new arrangement of May, 1928, under which the Lighting Department undertook certain work previously included in the price charged for gas, the price was 2s. 9d. from June 1, 1928, till Sept. 5, 1928; from Sept. 6, 1928, till March 8, 1929, it was 2s. 6d.; from March 9, 1929, till May 31, 1930, 2s. 4d.

THE NEWS—continued.

A Charming Entertainment.

Arrived now at their eighth season, the Metrogas Amateur Operatic Society have to their credit many productions, but on no occasion could they have given a more delightful time to their audiences than last week. No one can enter the Co-Partnership Institute at East Greenwich without the fact being at once impressed upon him that he is in a real Society of Friends. What, therefore, could be more appropriate than that the Metrogas Amateur Operatic Society should stage there "The Quaker Girl?" And what could have been happier than their interpretation of a piece the charm of which could be so easily spoiled, but was not? Throughout light and shade were delicately mingled, so as to give that pleasing effect which results from well judged contrast. Numerous were those who appeared on the stage, and those who comprised the orchestra; but nothing shall induce the writer to make comparisons. A compliment to all, however, may be deduced from his congratulations to Miss N. Webber, by whom the opera was produced, and to Mr. Sydney Herbert, the Musical Director. Both are old friends, who have long since won their spurs (by the way, do ladies "win their spurs?") on other fields. There is yet one other direction in which felicitations must be offered—to the South Metropolitan Gas Company, who are to be congratulated upon having in their service so much talent, and (it shall be added!) so much beauty. As the different scenes recur to mind, they seem to be accompanied by the words of the song, "I love thee." But, alas, it cannot be true!

Deal to Make Large Stock Issue.

An Extraordinary General Meeting of the holders of capital stock of the Deal and Walmer Gas Company will be held at the Company's Office at the Works in Cannon Street, Deal, on Friday, Dec. 19, 1930, at 12 noon, when the following resolutions will be submitted to the meeting:—

(1) That the existing mortgages or debentures to the aggregate amount of £7000 raised under the powers of the Deal and Walmer Gas Act, 1864, be repaid, and that six calendar months' notices be forthwith given to each holder for repayment.

(2) That the existing mortgages or debentures to the aggregate amount of £5600 raised under the powers of the Deal and Walmer Gas Act, 1914, be repaid, and that the requisite notices be given to the holders for repayment.

(3) That the existing mortgages to the aggregate amount of £8350, raised under the powers of the Deal and Walmer Gas Act, 1902, be repaid, and that the requisite notices be given to the holders for repayment.

(4) That in view of the capital requirements of the Company the Directors for the time being be authorized pursuant to the powers conferred on the Company by the Deal and Walmer Gas Act, 1864, the Deal and Walmer Gas Act, 1902, the Deal and Walmer Gas and Electricity Act, 1914, the Deal and Walmer Gas Order, 1927, and the Gas Undertakings Act, 1929, or some or one of them, to borrow on mortgage of their undertaking, and for that purpose to issue debenture stock to an amount not exceeding £50,200 to rank *pari passu* with any other debenture stock which may hereafter be issued with liberty to the Directors for the time being to issue the said sum of £50,200 stock at a discount, and at such rate of interest as may be fixed by such Directors, but not exceeding 6 p.ct per annum, and that such stock be issued either as irredeemable or as redeemable at par at the expiration of such period or periods as may be determined by such Directors, and generally on such other terms, and subject to such conditions as they may determine.

Rationalization in the Iron and Steel Industry.

The decision taken at a recent meeting of the Council of the British Engineering Standards Association to appoint an Iron and Steel Industry Committee is one which will have a far-reaching effect in the iron and steel industry of the country.

The decision was arrived at as a result of a resolution passed by a fully representative Conference held at the Institution of Civil Engineers on Oct. 17. The Conference was presided over by Sir William Larke, K.B.E., Director of the National Federation of Iron and Steel Manufacturers, and included representatives of upwards of 60 organizations and Government Departments, thus being fully representative of users and producers, and of the research and technical Institutions; the Conference being attended in their representative capacity by many of the leading engineers and technicians interested in the use and production of iron and steel.

The desirability of reducing the number and requirements of specifications to the simplest form consistent with modern needs, and the necessity for co-operation between users and producers to secure this result, was recognized by all speakers. The reduction of unnecessary differences between specifications and requirements for similar services could only be secured by such co-operation as would be rendered possible by the appointment of an Iron and Steel Industry Committee, through the operations of which it was confidently anticipated that productive efficiency would ultimately be increased. By the reduction of cost for a given service which must inevitably result, a stimulus would be given to the development of capital enterprise, which could not fail to have a substantial effect, as an important contributing factor in restoring prosperity not only to the industries concerned but to those dependent upon them.

Modern Gas Lighting.

An attractive folder has recently been published on behalf of the industry by the British Commercial Gas Association, setting forth by means of coloured impressions a range of beautiful gas lighting fittings particularly for the prepayment consumers. Here are shades in glass and silk—made in a variety of designs and colours. There are simple shades for hall or landing; attractive and dignified shades for sitting room, parlour, and bedrooms. The silk shades illustrated are supplied in six colours—cardinal, pink, flame, salmon, gold, and green. Particulars of dimensions and price are given over each illustration.

Notes from Scotland.

Price Reductions are announced as follows: Ballater Gas Department, by 1s. 7d. per 1000 c.ft.; Sanquhar Gas Department, from 6s. 8d. to 5s. 10d. per 1000 c.ft.; Oldmeldrum Gas Department, by 1s. 10d. per 1000 c.ft.

Following Complaints as to the inadequacy of the gas supply, the residents of Coaltown, Wemyss, have decided to send a deputation to the officials of the Wemyss Coal Company, Ltd., who supply the gas, to ask that the matter be specially considered at a meeting of the Directors.

The Auchterarder Gas Company show a gross revenue of £3412, and an expenditure of £3174, leaving a profit of £238. The Directors, having in view the necessity of conserving the liquid resources of the Company, recommended that no dividend or Directors' fees be paid for the past year, and this was agreed to.

FORTHCOMING ENGAGEMENTS

Dec. 6.—MIDLAND JUNIOR GAS ASSOCIATION.—Visit to Cannock and Rugeley Collieries, Hednesford.

Dec. 6.—SCOTTISH JUNIOR GAS ASSOCIATION (WESTERN DISTRICT).—Paper by Mr. W. A. Currie, of Glasgow, on "Continuous Verticals."

Dec. 6.—MANCHESTER AND DISTRICT JUNIOR GAS ASSOCIATION.—Visit to Messrs. J. & J. Braddock's, Globe Meter Works, Oldham. Paper by Mr. E. S. Davies, of Stretford, on "Waste-Heat Boilers with Horizontal Settings."

Dec. 6.—WESTERN JUNIOR GAS ASSOCIATION.—Visit to G.W.R. Gas-Works, Swindon.

Dec. 9.—FEDERATION OF GAS EMPLOYERS.—Meeting of the Central Committee, 11.30 a.m., 28, Grosvenor Gardens, S.W. 1.

Dec. 9.—INSTITUTION OF GAS ENGINEERS.—Meeting of the Education Executive Committee, 4 p.m., at 28, Grosvenor Gardens, S.W. 1.

Dec. 9.—NATIONAL GAS COUNCIL.—Meeting of Central Executive Board, 12 noon, 28, Grosvenor Gardens, S.W. 1.

Dec. 10.—SCOTTISH JUNIOR GAS ASSOCIATION (WESTERN DISTRICT).—Visit to Messrs. G. & J. Weir, Ltd., Cathcart.

Dec. 11.—MIDLAND JUNIOR GAS ASSOCIATION.—Paper by Mr. J. H. Wainwright, of Halesowen, "An Automatic Seal Arrangement for C.W.G. Plants."

Dec. 12.—LONDON AND SOUTHERN DISTRICT JUNIOR GAS ASSOCIATION.—Two short Papers—(1) "Refrigeration," by Mr. L. W. Andrew, B.A., B.Sc.; and (2) to be arranged later.

Dec. 13.—YORKSHIRE JUNIOR GAS ASSOCIATION.—Meeting at Leeds. Paper by Mr. L. Hartley (Messrs. Clayton, Son, & Co.) on "Waterless Gasholders."

Dec. 13.—WALES AND MONMOUTH JUNIOR GAS ASSOCIATION.—Meeting at Neath. Paper by Mr. R. T. Mills (Cardiff) on "Experiences in Fixing Gas Appliances."

Dec. 16.—SOCIETY OF BRITISH GAS INDUSTRIES.—Meeting of Council in the afternoon.

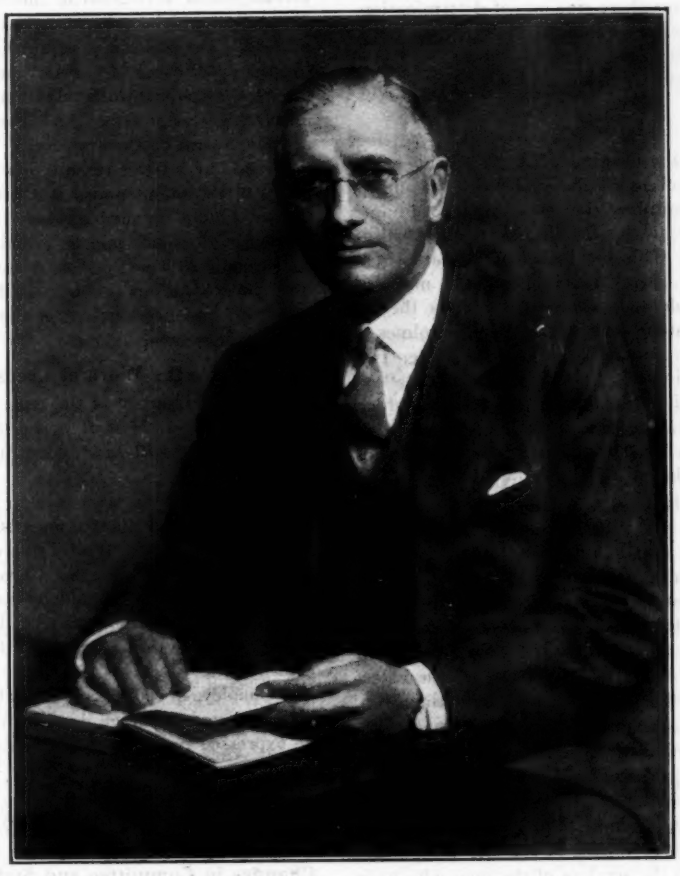
Dec. 17.—BRITISH COMMERCIAL GAS ASSOCIATION.—Executive Committee, 11.30 a.m.; General Committee, 2.30 p.m., 28, Grosvenor Gardens, S.W. 1.

INSTITUTION OF GAS ENGINEERS.

AUTUMNAL RESEARCH MEETING.

At the Incorporated Accountants' Hall, Victoria Embankment, London, on Nov. 25 and 26, 1930.

PRESIDENT - HAROLD E. COPP, M.INST.C.E.



HAROLD E. COPP,

Engineer and Manager of the Hull Undertaking of the British Gas Light Company, Limited.

Mr. Copp is the youngest son of the late Mr. W. L. Copp, who was closely associated for many years with the gas industry in the West of England, and was inventor of the first anti-dip valve for attachment to hydraulic mains, used extensively by London Gas Companies about fifty years ago. Educated at Wycliffe College, Mr. Harold Copp began his career in the gas industry in 1892 as a pupil under the late Mr. Fletcher W. Stevenson, at that time Engineer to the Sheffield Gas Company. Later, he acted as clerk of works on the construction of the Grimesthorpe station of the Sheffield Gas Company, and acquired considerable experience on large civil engineering works. He studied at Sheffield University College, gaining certificates in technical subjects, including civil engineering, metallurgy, and chemistry. In 1896, Mr. Copp left Sheffield to become engineering assistant to the Stockport Corporation Gas and Electricity Department, and was subsequently appointed Assistant Gas and Electrical Engineer. In 1902 he went to West Bromwich to take charge of the Corporation Gas Undertaking, where he designed and carried out many improvements and additions to the works. He also conducted a series of experiments on the enrichment of blue water gas by Peebles oil gas plant, worked in conjunction with the Dellwik-Fleischer blue water gas plant. In 1908 he was elected President of the Midland Association of Gas Managers. Mr. Copp's connection with the British Gas Light Company began in 1914, when he was appointed Engineer and Manager of the Potteries station, where he was responsible for the erection of one of the first plants for the production of benzole and toluol. The design of this plant was afterwards adopted by many other gas-works. On the retirement of Mr. John Young in 1919, Mr. Copp was transferred to the Hull Station, and since that time the works and plant have been largely extended and improved under his administration. The nominal capacity of the coal gas plant at the present time is 10,392,000 c.ft. per day, and that of the water gas plant, 4,300,000 c.ft. per day.

REVIEW OF PROCEEDINGS.

Followed by the Reports submitted and Discussions thereon.

A Remarkable Meeting Place.

On Tuesday of last week the Institution of Gas Engineers, under the Presidency of Mr. H. E. Copp, of the British Gas Light Company, Ltd., gathered to discuss research reports in the Incorporated Accountants' Hall, in which research workers in the gas industry were kindly permitted to hold sway for two solid days on the Tuesday and Wednesday of last week. "Solid," we think, is the right adjective; but it must not be assumed from this that business was without pleasure—most certainly it was with profit.

The severe and studious faces which filled the hall paid tribute alike to the President and to the idea of an autumnal meeting of the Institution. There was nothing flippant or gay about those present; the whole atmosphere was one of determination. The spell of pent-up will-power caught us in its grasp until, with commendable promptitude, the Secretary, Mr. J. R. Willis Alexander, read the notice convening the meeting.

A New Hon. Member.

Thus to the business of the meeting. The President—who, throughout the proceedings occupied the chair with an admirable reserve and dignity—mentioned that everyone whose name was on the recent list of candidates for election to the Institution had been duly elected. This list included the name of a new Honorary Member, Mr. Percy F. Holmes. The name of Mr. Holmes, said the President, is known throughout the industry, and as for the old-established firm of W. C. Holmes & Co., Ltd., it has been instrumental in establishing over two hundred gas undertakings in this country and abroad. "As you know, Mr. Holmes has instituted a new scholarship, which is called the William Cartwright Holmes Scholarship; this he has done in conjunction with Mr. Henshaw, who is also a member of the noted firm of Holmes."

On rising to reply, Mr. Holmes was greeted with well-deserved applause. "I thank you," he said, "on behalf of myself, on behalf of my firm, and more especially I thank you on behalf of the whole of the gas engineering firms similar to my own, because I feel that this honour you have bestowed upon me is a compliment to them all, and has been given to me, not so much for any merit on my part, but as a recognition of the fact that I am, fortunately or unfortunately, the oldest member of the gas engineering firms at the present time."

Mr. Holmes went on to say that their reason for instituting the scholarship at Leeds University was that they appreciated the tremendous amount of good work which has been done by the Leeds University and other Universities of a similar nature, not only on behalf of gas supply undertakings but also on behalf of firms such as his own. "We have," he said, "derived very much benefit from the services of the men who have come to us from the Universities, and in making a small donation to the Leeds University we felt that we were merely repaying in a small way the debt we owe to it."

New Diplomés.

Mr. Samuel McGown, of Glasgow, then went up to the platform, where he was presented with a 1st Class Diploma Certificate in Gas Engineering by the President, who mentioned that the recipient represents the third generation of gas engineers. Two other Diplomas in Gas Engineering (2nd Class) were presented—one to Mr. R. L. Greaves, of Wolverhampton, and the other to Mr. D. J. Ward, of Birmingham.

Mr. McGown was also presented with the Charles Hunt Memorial Medal. In doing so, the President suggested that the time was opportune for expressing the thanks of the Institution to Mr. Hunt's family.

A Departure in Co-ordination.

For the first time we had a report from the General Research Committee, which body supervises and co-ordinates the research work of the Institution, and particularly that of the Joint Research Committee of the Institution and Leeds University and of the Research Sub-Committees; subject to the Council of the Institution, it directs what research work shall be done, and what financial appropriations shall be made for this work, and is responsible for the appointment of research staff. The report indicates the work during the period 1929-30 of the Joint Research Committee, the Sub-Committees, and the Gas Research Fellow. As we shall outline most of this work under separate headings, it only remains here to mention the investigations in relation to calorimeters, gasholders, and purifiers, all of which matters are in the hands of special Sub-Committees. The Calorimeters Sub-Committee has been ascertaining the experiences of users of recording calorimeters, and it is intended to publish later a comprehensive report for the guidance of gas engineers. All members of the Institution are already aware of the request of the Gasholders Sub-Committee, made by a letter recently circulated, for co-operation in relation to the maintenance and inspection of holders; the question of giving detailed guidance to gas engineers, though at present it does not appear practicable, is being given further consideration. The Purifiers Sub-Committee have been delving into the precautions taken by undertakings to avoid explosions and fires, and have arrived at the conclusion that every proper precaution is being taken.

A Tribute to the Work at Leeds.

In a brief survey of the report, Mr. Copp paid a tribute to Prof. Cobb and his staff at Leeds University, who are doing "work which will bear good fruit for the industry in the future."

Mr. W. T. Dunn then rose to speak about several matters. He first suggested that the members ought to bear in mind the pioneer work of Mr. John Terrace and the debt which the industry owes to the late Sir Corbet Woodall. He then urged that more attention should be paid to the æsthetic aspect of gasholder construction. Finally, he referred to the problem of effluent liquors, and suggested that the Committee ought to consider the effects of discharging such liquors into the sea. Mr. Shapley, in reply, said that altogether too much stress has been laid upon damage done to fish by effluent discharge, and he expressed the hope that it would not go forth that at a research meeting of the Institution the subject was viewed with alarm. "I think," he remarked, "that we can be practically certain that damage to fish life by discharges of effluents from gas-works is negligible."

Changes in Committee and Staff.

The next item on the programme was the presentation of the 26th Report of the Joint Research Committee—in other words, the 2nd Report on the Use of Creosote in the Manufacture of Carburetted Water Gas. This report is preceded by a general introduction to all this year's reports of the Joint Research Committee by Prof. Cobb, who mentions that Mr. John Terrace has taken the place of Mr. Thomas Glover, who has retired from the Committee, and that two additional research workers—Mr. E. Parrish and Mr. N. H. Williams—have been appointed to the staff. Also, Mr. W. J. G. Davey holds the post formerly occupied by Mr. G. B. Howarth, who is now Chief Chemist to the Newcastle and Gateshead Gas Company.

Laboratory Work on Creosote.

From previous work, it appeared that the most promising method of utilizing creosote for the manufacture of carburetted water gas was to employ it admixed with a larger volume of

petroleum gas oil. Consequently a laboratory investigation was carried out to ascertain the merits or demerits of this method. The results, as set out in the 26th Report of the Joint Research Committee, do not make pleasant reading. They show the low thermal yields of gas when creosote is cracked under conditions which obtain in practice; the amount of tar is correspondingly high, and this tar contains five or six times as much naphthalene as does the tar obtained when gas oil is used. As a matter of fact, when creosote is mixed with gas oil, the results are slightly worse, from the gas-making point of view, than those gained when creosote is employed alone. Hence the conclusion that, although dilution of the creosote with gas oil may avoid mechanical troubles on the plant, the presence of the gas oil does not increase the thermal yield of gas given by the creosote, above the low value obtained when using the creosote alone.

The investigation of the cracking of creosote is being continued, under conditions of temperature and atmosphere not imposed by those normally existing in the carburettor and superheater of a carburetted water gas plant. The highest thermal yield of gas obtained so far in these experiments is 0·83 therm. This figure is the result of an experiment in which light creosote was cracked in an atmosphere of hydrogen at 1100° C. Under such conditions, no liquid tar was obtained and the amount of naphthalene produced was relatively small. A considerable quantity of sooty matter was formed, however, and was deposited in the cool gas exit from the furnace. Further experiments will be carried out at lower temperatures with particular regard to the yield of light oils obtained.

Side Chains.

In the discussion on the report, Mr. R. H. Griffith, of the Gas Light and Coke Company, spoke about the large difference between the results obtained with light and with heavy creosotes. He pointed out that the whole nature of the oil composition is not revealed by the simple group analysis. Although the group analysis shows the difference between naphthalenic and aromatic cyclic hydrocarbons, it does not show the presence or absence of side chains on the aromatic nucleus. In the petroleum hydrocarbons there are, he said, generally side chains of varying length which can yield methane or ethane or other rich gas by their decomposition. The difference between petroleum hydrocarbons and those obtained by high-temperature carbonization of coal is that in the former there are these side chains, but they are not present in the latter. He suggested that the results reported by Dr. Dent represent the maximum that can be hoped for from creosotes produced by high-temperature carbonization.

A New Carburetting Technique.

Attention was called by Dr. G. W. Anderson, of the Gas Light and Coke Company, to the virtues of injecting creosote into the generator itself. He mentioned that within the last twelve or eighteen months a process on these lines has been in operation at the works of the Frankfurt Gas Company. Ordinary coal tar or lignite tar is injected into the fuel bed of the water gas generator. It is not a new process, but it appears that the Company have overcome the technical difficulties which usually accompany the cracking of tar in the generator bed. Dr. Anderson observed that complete details are available in regard to the cost of operation and the cost of plant. It seems possible to do away with the superheater and the carburettor, " in which case we should reduce materially the cost of plant, which is said to be about 20 or 25 p.ct. higher than that of ordinary blue water gas plant." Mr. Thomas Hardie said that a system similar to the one in use at Frankfurt has been common practice for some years in the United States, where they are using heavy oil with great success. In this country already a generator has been constructed, embodying the necessary modifications to enable this to be done; and Mr. Hardie expressed the hope that shortly it will be possible to give particulars of the use of creosote in this way.

The Back-Run Process.

The final item of the morning session on Tuesday was the presentation of the 27th Report of the Joint Research Committee, on the back-run process for the manufacture of carburetted water gas. The plant on which the tests were carried out is at the Stratford Works of the Gas Light and Coke Company, and is a Humphreys & Glasgow. The report is essentially of a preliminary character; but the collected tables summarize the results of a much more complete thermal and chemical examination of the process than has ever been carried through before. The thermal efficiency is given as 69·3 p.ct.—a useful figure to remember. The report is preceded by an introduction dealing with the advantages claimed for the back-run process, the development of which took place in America. The process, as commercially practised, is due to Young, and in his simple plant, consisting of generator, carburettor, and superheater, this method of working recuperated heat from the blow gases which would otherwise have been lost, and returned this heat to the generator, with a consequent saving in fuel. When the fuel used was of a bituminous character, the loss of distillation products in the blow gases was reduced. The restoration of heat to the generator by the back-run steam enabled the ratio of gas-making time to blowing time to be raised, so increasing the capacity of the plant per day and reducing the tendency to clinker formation. American experience also indicates that passing steam through the carburettor and superheater gasifies carbon deposited from the oil, leading to a longer life of the chequer work and an improvement in its condition, or, alternatively, permits the use of oil of a lower quality.

Mechanically, the process has the advantage that the necessity of the troublesome " hot valve " in the carburettor-to-generator main is eliminated. The difficulty of keeping a " hot-valve " steam tight is particularly acute when bituminous fuel is used in the generator, as this causes a sticking of the valves due to pitch and tarry accumulations. In America it is claimed that the back-run, in overcoming this difficulty, widens the range of fuels which can be economically used in the generator.

Maintaining the carburettor and superheater at a higher temperature than normal, with, however, a cooler zone at the top of the superheater, reduces the potential and sensible heat of the waste gases leaving the set, and, consequently, if the plant is equipped with a waste-heat boiler, it is to be expected that the performance of the boiler will be reduced.

It is evident, states the report, that some of the advantages of the back-run process as practised in America lose their importance under the conditions existing in this country. The plant at Stratford, besides being fitted for back-run steaming, is constructed with a self-clinkering and steam-producing generator, and is operated by automatic control. The combination of all these features improves the conditions in the fuel bed and strikes a new balance for the utilization of the waste heat.

In some American installations, during the back-run, water is injected as a fine mist into the top of the superheater in place of the more usual steam. This procedure increases the amount of heat carried back to the generator; and the claim is also made that, using effluent liquor in place of water, the practice gives a satisfactory method of its disposal. This could hardly apply, however, to effluent liquor loaded with lime salts.

Practical Advantages of the Back-Run.

The discussion to which this report gave rise was both lengthy and valuable. Mr. E. J. Hutchence, Engineer at the Stratford Works, was the first to speak; and he dealt with the practical advantages of a back-run plant, comparing the results with those given in the Sixth Report on blue water gas and the Seventh Report on carburetted water gas. The notable features, he said, are the increase in the amount of steam decomposed, the greater thermal yield per ton of coke, the greater yield of dry tar, and the marked reduction in the percentage of carbon in the clinker. The back-run automatically operated rotary grate sets at Stratford have been in operation for two years, and there have been no major repairs. The wear and tear expenditure, including the entire plant and auxiliaries, is only 0·6d. per 1000 c.ft. of gas made.

It was explained by Mr. T. F. E. Rhead that the Birmingham Corporation Gas Department are about to start up two automatic water gas plants, each of a capacity of 2¾ million c.ft. a day, and that therefore the report would prove very valuable to the Department. It will, he said, be useful to know, as the

work goes on, to what extent the capacity of the plant is increased by the sweeter working of the generator occasioned by the use of the back-run. He expressed his interest in the relative figures of the steam produced in the generator boiler and the waste-heat boiler, 29·2 units in the generator boiler as compared with 38·2 units in the waste-heat boiler—a remarkably large percentage of steam from the generator boiler. He was under the impression that these sets were self-steaming. Dr. Parker warned investigators against trying to draw too many conclusions from a comparison of output of the plant described in the Seventh Report and that dealt with in the report under discussion. "The main point," he said, "seems to be that improvements are attained by self-clinkering grates and by automatic operation of the plant, but I do not consider it yet proven that there is any distinct advantage in the back-run process, especially if it means a reduction in the amount of steam raised in the waste-heat boiler following the superheater. No doubt, however, the tests which are to be carried out on a plant which can be operated in both ways will provide an answer to this question."

Mr. C. M. D. Belton corroborated from his own experience the suggestion made in the report that there is a definite advantage due to the use of the back-run, owing to the fact that the temperature variation throughout the plant is not so great, though he does not agree that much clinkering time is gained by the use of a mechanically operating grate. Dr. S. Pexton suggested that there has really been very little difference between the temperatures of the fuel beds in the Stratford test and the tests recorded in the Seventh Report. In his opinion it is not the length of time which controls the temperature in the fuel bed, but rather the quantities of air and steam admitted during the cycles. Mr. Williams, of the Fuel Research Station, called attention to a method of sampling developed at the Station whereby one can "determine correctly the amount of blue water gas produced during an up-run, or back-run, or any other run." Also, he put in a strong plea for the direct determination of the amount of blow gas, or the amount of carbon utilized in the blow gas. Here again he provided the necessary recipe for carrying this out.

The question of the steam generated by a back-run plant was referred to again by Mr. F. Nicholls, of Newcastle, who thinks that the figure of 85 p.ct. of the total requirements, given in the report, is too high. He pointed to the difference between the steam consumptions of intermittently and continuously operated plants, and suggested that it is as well not to strive after too low a carbon content in the clinker. He favours the view that the case for back-run steaming has not been made out. The President's experience of the system is that the wear and tear on the plant is distinctly heavy, but that the financial advantages accruing from its operation, as compared with the ordinary water gas sets, are most marked.

An interesting fact mentioned by Mr. T. Reynolds, of Blackpool, was that, by the installation of the back-run process, a water gas plant of a nominal capacity of 700,000 c.ft. a day had its output increased to 1,300,000 c.ft. a day, without any structural alterations other than the fans of the back-run process.

Replying to the discussion, Dr. Dent observed that the amount of heat taken back in the back-run steaming can be used two or three times more efficiently than in the waste-heat boiler.

Products of Combustion.

The ball was set rolling on Tuesday afternoon by discussion of the 25th Report of the Joint Research Committee—An Examination of the Products of Combustion from Typical Gas Appliances; Part V. The appliances examined include a surface-combustion water heater, the Fairweather calorimeter, and the inverted incandescent mantle burner. The results demonstrate how very small is the amount of carbon monoxide generated with the surface combustion heater. The particular heater examined was intended to consume 100 c.ft. of gas per hour and to heat 40 gallons of water per hour through 100° Fahr.

At 100 c.ft. per hour the combustor surface attained a moderate red-heat, and at 140 c.ft. per hour a bright red-heat. With 10 to 15 p.ct. excess air the CO production was less than 2 parts per 10,000 of gas burned, or 0·05 part per 10,000 in the exit gases from the appliance. With less than 5 p.ct. excess air—a condition which ought not to arise in practice, because of the characteristic appearance of the combustor surface—the production of CO rose very rapidly. The thermal efficiency of the apparatus was about 80 p.ct. on the gross calorific value of the gas used.

As for the Fairweather recording calorimeter, the CO production was comparable with that of free-burning flames; and thus it was established that the instrument is such that no error can arise from the presence of products of incomplete combustion.

Perhaps the most interesting section of the report concerns the results of tests on the inverted mantle burner. The rate of CO production is considerably higher than that given by free-burning flames. But it is lowest over that range of gas rate at which the burner will be normally used; the total amount of carbon monoxide produced is small; and the CO-concentration in practical operation is harmless. However, the results show that, from the standpoint of economy, efficiency, and hygiene, it is not desirable to operate an incandescent mantle burner at a rate much below its normal working rate. The report emphasizes that it is advisable to use small burners and mantles for low gas consumptions, rather than to turn down the gas supply to a burner and mantle of larger size.

Scorch Diagrams.

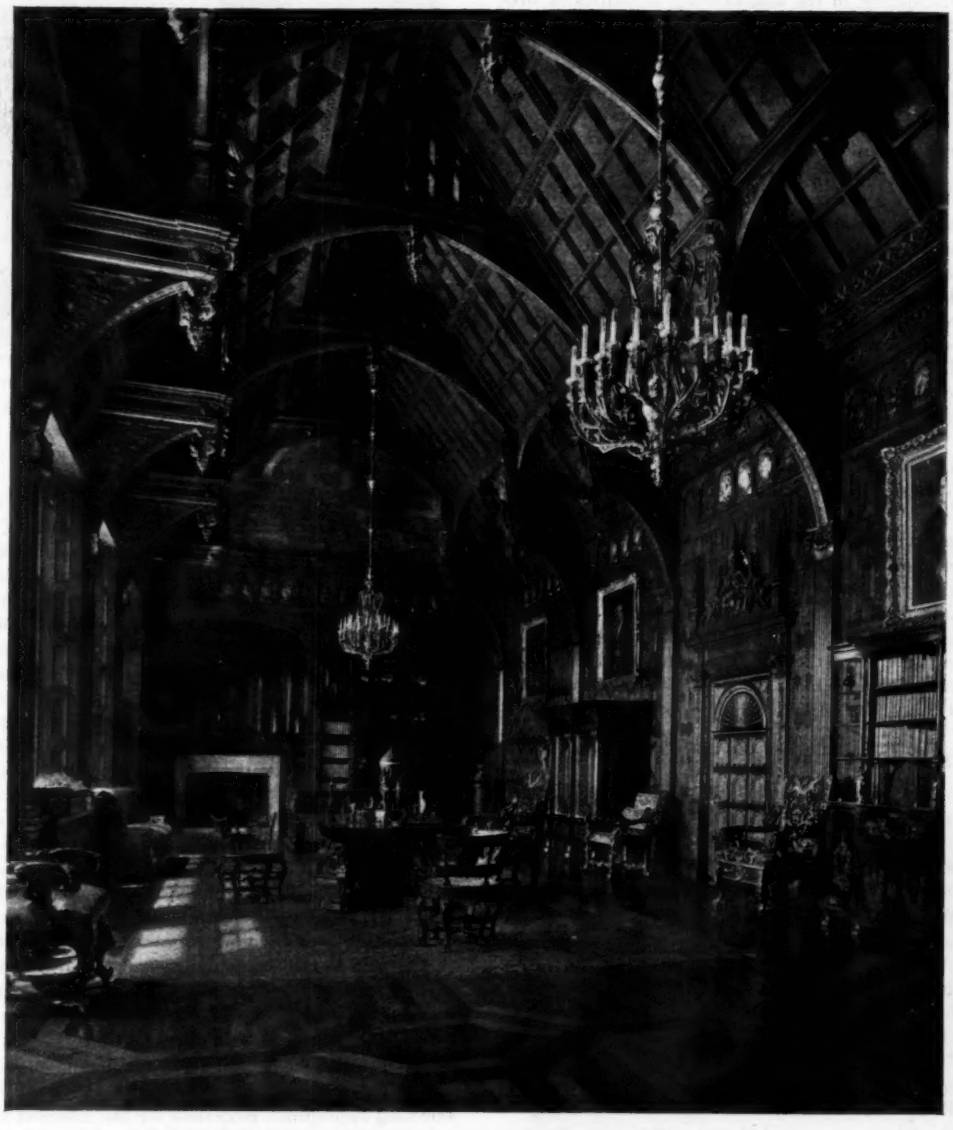
There are four appendices to Mr. Wood's report. The first deals with a simplified iodine pentoxide apparatus for the determination of small amounts of carbon monoxide; and a considerable speeding-up seems to be possible if a high order of accuracy is not required. The second is a note on carbon monoxide recorders. The third outlines some of the features of design of Continental gas appliances; and the fourth appendix, which we reproduce in extenso in this issue of the "JOURNAL," describes a pyrographic method of examining the flames of gas appliances. Circular pieces of wood, which represent the bottom of a pan, are exposed to the flames, and the scorch diagram is examined. In the Tegel Laboratories of the Berliner Städtische Gaswerke, the preparation of these pyrographic diagrams forms part of the routine testing of gas cookers. Results obtained by this method cannot be expressed quantitatively, but they form a permanent record, and to an experienced worker convey information which cannot be obtained by visual inspection of the burner either with or without a pan in position. They are also useful for indicating to consumers and sales staffs some of the conditions under which combustion takes place. No appliance would be passed merely because its scorch diagram was satisfactory. On the other hand, a poor scorch diagram would indicate the desirability of going further with thermal efficiency tests and the chemical examination of the products of combustion from the burner.

Cluster Burners and Flueless Heaters.

The contribution made to the discussion by Mr. J. G. Clark, who was the first speaker, is most valuable; and his remarks will be studied with great interest. He asked, first, that consideration should be given to the formulation of some standard basis for expressing "combustion efficiency," and suggested the $CO : CO_2$ ratio. He urged, too, that a sense of proportion should be maintained in the interpretation of the results of combustion in gas burners. Another matter he dealt with was the cluster lighting burner. With such a burner we cannot adjust any one of the flames to fit any one mantle; they must all be adjusted together as a complete unit, so that if we have mantles varying considerably in size on one burner we may adjust the flame to suit one mantle, but not the others. Hence we must have mantles of very nearly the same size. This matter is important, "and if," said Mr. Clark, "it has not received attention everywhere, I advise that it should be considered. It is quite easy to obtain mantles of similar dimensions. We in the Gas Light and Coke Company specify certain minimum variations in the dimensions of mantles; unless we do this, we do not get the best lighting effect from the cluster type of burner." The speaker's tests on surface combustion appliances confirm the results obtained by Mr. Wood,

and suggest the use of a governor with all such apparatus. Perhaps the most interesting of Mr. Clark's remarks, however, concern the flueless heater. His view is the definite one that quite a number of modern flueless heaters are exceedingly good. The combustion of these stoves is so good that they may actually purify the air of the room in which they are placed, and reduce the content of carbon monoxide.

Another matter referred to by Mr. Clark was that of convection heating. His feeling is that, as an industry, we shall very soon have to turn sharply against our ideas that radiation is the all-important factor, and shall have to provide more convection. "I am sure," he said, "that we shall not be able to increase the use of gas fires in living rooms almost continuously until we have a substantial amount of convection added to the radiation emitted from the stoves." In regard to Mr. Wood's observations on pyrographs, Mr. Clark mentioned that tests on similar lines were carried out by the Gas Light and Coke Company five years ago.



INCORPORATED ACCOUNTANTS' HALL—THE GREAT HALL.

Expression of Results.

Mr. Wood, in reply to Mr. Clark, suggested that the CO : CO_2 ratio is quite satisfactory in some ways, but the disadvantages are that the CO_2 production of the gas per c.ft. is itself liable to some variation, and the CO : CO_2 ratio does not give any idea of the actual output of CO. For that reason two figures are given in the report—the output of CO per 10,000 c.ft. of gas burned, and the total output of CO, in c.ft. Mr. Wood mentioned that he examined a flueless heater, and found the combustion "remarkably efficient;" and he thinks with Mr. Clark that the convector will come back into use in the industry considerably, though not to the exclusion of the radiant type of gas heater.

Risk of Misinterpretation.

Mr. W. J. A. Butterfield called attention to the fact that research reports circulate outside the immediate circle of members of the Institution. Hence he suggests that in future reports an additional method of stating the results should be included. We should, he suggests, assume that in any given room there is an accepted standard of ventilation, based on the proportion of CO_2. "Take the factory daylight standard of 10 parts of CO_2 per 10,000, and state, in regard to each appliance, at its worst, what the proportion of CO would be in the air of a room when 10 parts of CO_2 per 10,000 are present in the room, derived from the gas appliance. Then the proportion of CO would be shown which may occur in the air of the room in its real proportions, and any member of the public, when reading it, would not misunderstand."

Mr. Wood, while agreeing with Mr. Butterfield's general principle, observed that the products of combustion are not, or

may not be, uniformly diffused throughout the apartment, and we have to consider the case of a person who might be placed relatively close to an appliance and who might be subjected to greater concentration of the products of combustion than will prevail throughout the greater space of the room.

Refractory Materials.

The 21st Report of the Refractory Materials Joint Sub-Committee was then presented. This consists of a summary of recent investigations, by Mr. A. T. Green, and a treatise by the same author on "Observations on the Behaviour of Refractory Materials in Continuous Vertical Retorts." The abstracts of the first section include the findings of work on the influence of atmosphere on the load-bearing capacities of firebricks (H. T. S. Swallow); on the determination of the properties of quartz, cristobalite, and tridymite, on the determination of the reversible thermal expansion, and on the effect of iron oxide and a reducing agent on the rate of inversion of quartz (W. J. Rees and W. Hugill).

Mr. Green's contribution is a most valuable one. Characterizing the systematic study of the condition of retorts after their effective life as a source of valuable data, he says that in this work information concerning (1) the internal dimensions of the retort at all levels; (2) the condition of the retort brickwork at all levels—based on a "brick to brick" examination; (3) the condition of the combustion chambers; (4) any other peculiar features, should be obtained. Samples of the materials from the various zones should be taken and subjected to laboratory examination. When studying this information it is essential to keep in mind (1) the history of the working of the setting; (2) the limitations in the properties of refractory materials under general carbonizing conditions; (3) the individuality of the carbonizing system; (4) the probable local peculiarities in operations; (5) the nature and influence of the coal used. The result of the work should be an attempt to assess the chief factors causing decreased durability. The records, which must form a very serviceable basis of reference and indicate principles for the improvement of the existing practice, should then be carefully filed. This systematic procedure appears to be the only one capable of explaining the general and the particular features governing the life of a setting. It will certainly result in opinions which are not in keeping with the bald statement that "the refractory materials were at fault."

Influence of Slags.

The author considers in turn the initial heating-up of retort settings; the examination of retorts after operation; and the influence of slags. On the last-named subject he observes that slag actions will take place in all vertical retorts, the extent being dependent on (1) the nature of the inorganic constituents of the coal; (2) the design of the retort; (3) the manipulation of the retorts, particularly with respect to the temperature of working and the extent of steaming. The influence of the slagging action may be very injurious in causing (1) erosion, that is, the rubbing away of the slagged surface by the charge; (2) failure of the brickwork through acute slag penetration; (3) "sticking" of the charge. All three types of trouble are often encountered in retort working. The ability of the siliceous and the silica products to absorb ferruginous slag is a good property, for it tends to prevent slag accumulation on the surface, which would seriously alter the lines of the retort and influence the passage of the charge. Flaking and spalling, jointing cements, and the conditioning of hot and cold retorts follow an outline of an investigation of four settings of retorts in different parts of the country, prior to and during dismantling. Mr. Green emphasizes the need for rigid examination of hot-patching cements.

In his concluding paragraphs, the author states that, starting with very high grade refractories and an adequate cement, there are actions consequent on the nature of carbonization which will ultimately cause the materials to fail. By proper care in the manipulation of the retorts, however, a profitable life should be obtained from a setting of high-grade material and adequate cement. There are many problems which, when solved, will lead the way to a material increase in efficiency. The method of "trial and error" seems to be the only one which will eventually prove successful.

One of these problems is the selection of the refractory materials of construction. The paper indicates the zonal nature of certain of the troubles. It is feasible, therefore, to suppose that different types of refractories are required for the different zones. It is reasonable to think that a special type could be developed to resist the flaking action better than a silica brick. The introduction of this new type over some four feet of the retort length might cut down flaking to a minimum and reduce the necessity for hot-patching of the top zones. At the moment it appears that the possible refractories which could be used for high-temperature carbonization and would resist flaking must be comparatively costly. If, however, such products increased the certainty of continued operation by 500 days, they would amply repay the extra cost. Similarly, the zonal nature of vertical retort working suggests that the constitution of a cement must vary with the zone of the retort. It is along these lines that progress with gas-works refractories is likely to be made.

Prior to the introduction of the report, Dr. Colman referred to the loss which the Refractory Materials Joint Sub-Committee sustained through the death of Mr. J. P. Leather, who rendered distinguished service to the Committee during his long period of Chairmanship. Dr. Colman also appealed for funds, in order to widen the scope of research and make it more effective. The first speaker in the discussion was Mr. Frank West, Chairman of the Society of British Gas Industries, who supported the author's suggestions regarding the great care necessary in the heating-up and cooling-down of settings. On the matter of permeability, Mr. West contends that some quantitative definition of this feature is essential, at both low and high temperatures.

Zonal Materials.

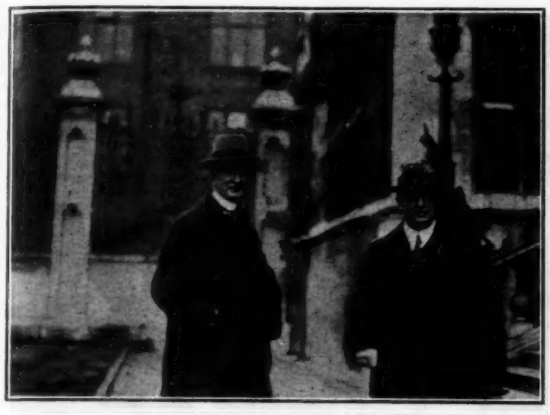
The next speaker was Mr. C. M. D. Belton, who prefaced his remarks by an expression of regret that the various reports had not been available earlier to members of the Institution. He suggested that the author's experience has been with retorts constructed throughout of the same material. Mr. Belton has a setting in which use has been made of different materials in the different zones of the retort, and he thinks he has now arrived at a construction which gives good results continuously. He is using a 95 p.ct. silica material for a depth of from 8 to 10 ft. in the intense combustion zone, a material of lower siliceous content for the lower section of the retort, and an aluminous material for the upper 4 or 5 ft. This form of construction has enabled Mr. Belton to avoid the serious pitting which previously occurred at the top of the retort, and has enabled him to attain high temperatures without damage in the combustion zone itself. Mr. Belton also emphasized that great care must be given to scurfing. Unless the scurfing is carried out carefully, considerable areas will flake; but if proper attention is paid to the regulation of temperature, and if we are not in too great a hurry to get rid of the scurf, and do not send unregulated blasts of air or steam through the retorts, deleterious effects may be minimized.

The President appealed for a greater pooling of knowledge, and he confirmed what Mr. Belton said about the importance of selecting appropriate materials for the different zones. He too has adopted this method with gratifying results. As to spalling and flaking, he suggested that a useful way of obtaining records would be to employ plaster casts, to which Mr. Green replied that the taking of plaster casts on the inside of a retort, with all the dirt in one's eyes, would be a delightful occupation. Mr. Shapley asked whether, if a silica cement free from added fusible ingredients is used for the re-conditioning of cold retorts, any flaking-off of the cement occurs when the retorts are brought into use. He has patched his retorts in a thorough manner, and they have stood up remarkably well until the first scurfing, but then a large proportion of the material has come off, and the flakes have been so soft that they could easily be reduced to dust between the fingers. Mr. Green said that cold patching serves two purposes. In the first place, by so doing we endeavour to put a surface on the retort, which certainly may come off during the first scurfing, but, in the second place, the

patching tends to knit up the material at the surface; thus, although the actual skin of the patch may come away during the first scurfing, there is definitely an advantage in cold patching.

External Corrosion of Pipes.

Tuesday's session came to an end by presentation and discussion of the 1st Report of the Corrosion of Pipes Sub-Committee. The work undertaken by the Committee was concerned with external corrosion and its prevention by protective



coatings. It may well be, states the report, that in the future, owing to the increasing practice of distributing partially dried gas, so far as internal corrosion is concerned, the choice of material (cast iron, wrought iron, and steel) will depend less on considerations of resistance to corrosion and more upon first cost and mechanical suitability. On the other hand, the protection of pipes—service pipes in particular—against external corrosion becomes increasingly important. The investigation described in the report involved the examination of various materials and methods used for the protection of pipes against external corrosion; and the work was carried out by two different methods in the laboratories of the Gas Light and Coke Company and the South Metropolitan Gas Company.

External corrosion, it is pointed out, may be due to contact corrosion by the soil or by electrolysis; in any event, corrosion is a galvanic phenomenon. The electromotive force set up may be small (soil corrosion) or large (stray electric currents). Corrosion may be obviated by preventing water coming into contact with the metal or by applying a reverse electromotive force to render the metal neutral or cathodic. The second method is, generally speaking, impracticable. [The earthing method, though mentioned, is not considered.] The report therefore confines attention to protective coatings. The latter should possess high specific electrical resistance, be resistant to chemical attack, be mechanically strong, be unaffected by age, and be easily applied to the pipe. The available coatings are paints, bitumens, pitch, impregnated fabrics, Portland cement, and metallic coatings; and the report concerns itself chiefly with the waterproofing qualities of various paints. The value of waterproof wrapping for protecting a pipe against stray electric currents is indicated; and it is shown that the protection against stray electric currents afforded by cement-sand mixture is only temporary, though observations show that this mixture is a fair protection against contact corrosion.

A very interesting portion of the report deals with the danger from faults in coating. The pipes tested were laid in soil exposed to atmospheric conditions. Examination of the pipes after removal revealed that in the case of the unprotected pipe, electrolysis was distributed all over the surface of the pipe. A marked characteristic of the protected pipes was that the centres of electrolytic action were distinctly local in character. The whole surface of the pipe was not pitted in these cases as with the unprotected pipe, but the pits were considerably deeper, and, moreover, were deeper the greater the number of protective coatings. Therefore, if pipes are to be protected against electrolytic corrosion, such protective coatings as are employed must be well applied, otherwise efficient protection against corrosion may be achieved only at the expense of an intensified local electrolysis. With contact corrosion, faults in the protective coating have not quite such serious effects as with electrolytic corrosion. Nevertheless, the importance of complete protection cannot be over-emphasized, because one local defect in a service pipe is sufficient to render the whole pipe unsound and to necessitate its replacement.

Need for Specification and Further Work.

The Corrosion of Pipes Sub-Committee realize the need for specifications for protective coatings and for a generally accepted method of testing. The available information, however, is not yet sufficient for this.

The investigation described in the report has, however, already had important results. A considerable number of samples of pipes coated by tube manufacturers have been tested, and the results made known to the manufacturers concerned. Many of the tube manufacturers have been working at the problem themselves, and have substantially improved their pipe coatings. For this reason, and others, the Sub-Committee have not thought it desirable to publish particulars of individual tests.

Cast Iron versus Steel.

Mr. R. H. Ruthven presented this report in a very pleasant manner. Following the President, Mr. L. H. Sensicle said how thoroughly he favoured the method of using low voltages for testing the wrapping of pipes. He himself has carried out a series of experiments on such lines, and as a result he came to the conclusion that it is not necessary to run the tests for a whole year. "In about a month," he said, "one could tell with certainty whether or not a certain wrapping was going to be successful." The best type of wrapping he found was bitumen hessian—which was prepared by the Gas Company (presumably the Newcastle Company), and not by outside manufacturers. Mr. Stephen Lacey was the next speaker, and he observed that for the last twenty years the relative merits of cast iron and steel have been argued, but cast iron has largely held its own, "because the experience of a century has shown that it has an extraordinarily, and surprisingly, high degree of resistance to corrosion in normal circumstances, and, secondly, there has been no convincing proof forthcoming that the wrapping of steel pipes will be permanently effective." It is, of course, surprising that the manufacturers of steel pipes, who

must necessarily be interested in obtaining an effective protective coating, have done relatively little in the last twenty years. As Mr. Lacey observed, the wrapping supplied now with steel pipes is substantially the same as that supplied twenty years ago. "There are available to-day," he remarked, "protective coatings which are not wrappings, but really asphaltic coverings, which hold out great promise . . . and if those coverings prove to be as good as they appear to be, the relative positions of cast iron and steel may be altered." However, the Committee was concerned chiefly with service pipes—in other words,

wrought iron and steel. In either case, under modern conditions, protection against corrosion is necessary, particularly in view of the high cost of reinstating paving. "A wrapping," said Mr. Lacey, "is nothing more than a means of holding in place the pitch or bitumen material."

Dr. G. W. Anderson spoke of the advantages of a certain wrapping which he has tested; and Mr. Ruthven replied that the Committee tested this particular material, but that, for obvious reasons, they could not give the results of individual tests. Mr. Botley suggested that practically perfect protection against soil corrosion is afforded if service pipes are laid carefully in pitch in troughing. The President, too, said that he had never known a service to become corroded when laid in this manner; but Mr. Lacey pointed out that it is difficult, if not impossible, to employ this method in the congested subsoil of city streets. In London, for example, it is necessary to run service pipes under and over various obstacles; and these obstacles are so numerous that it becomes much easier to apply a wrapping.

Ring Out the Old, Ring In the New.

The old Institution of Gas Engineers met at 10.15 on Wednesday morning for the last time, to receive an account from the Liquidator (Mr. J. R. W. Alexander) as to its winding-up. Having explained that the legal formalities had been complied with, Mr. Alexander, in a happily phrased speech, brought the Institution's honourable career of twenty-eight years to an end. "This old Institution," he remarked, "has made itself the more remarkable by combining with its decease the birth of a lusty infant, the Chartered Institution of Gas Engineers—an infant which, judging from its distinct achievements of the first eighteen months, will pay its distinguished parent the greatest compliment of all, that of attaining even greater eminence than its progenitor." As to the future, Mr. Alexander said: "Wise men there are who, while acknowledging the service of the industry to the common weal in the past, wag their heads as to the future, and express the conviction that the gas industry must inevitably decline. Apart from drawing attention to the uncanny regularity with which such folk receive their dividends, and to the capital which the industry is so readily able to command, the best answer, since it is unbiassed, to such criticism is to be found in the Board of Trade Returns. Those for last year show an increased sale of gas of 3·6 p.ct., which is equivalent to the output of Glasgow or the combined sales of Leicester and Liverpool. More gas has been sold per consumer, and, in

spite of bad trade and unemployment, the addition of a quarter-of-a-million consumers in 1929 brought the total figure to over nine millions, in whose service gas mains have been increased nearly ten thousand miles in length during the past ten years."

The President, who spoke of Mr. Alexander as an energetic and capable Secretary, thought the members should feel no sadness at the obsequies of the old Institution. He also expressed the gratitude of the Chartered Institution to Mr. Shrimpton for his work in connection with the obtaining of the Charter.

Liquor Effluents.

Dr. Monkhouse then presented the 5th Report of the Liquor Effluents Sub-Committee, and he did so in a manner which was thoroughly appreciated by all present and which reflects the greatest credit on him. The activities covered by the report are summed up by Prof. Cobb in an introduction. At the Coventry Gas-Works, the operation of a cyclone tar extractor on a Glover-West setting of vertical retorts has been tested out, and the results are reported along with those previously obtained by the use of the Lodge-Cottrell electrostatic tar precipitator at Hinck-

ley. A test of considerable duration and complete success has been made on the disposal of effluent liquors by evaporation on the bar grates of gas producers at the Hinckley Works. An evaporation has been obtained which corresponds with the disposal of 37 p.ct. of the total effluent liquor produced, consisting of the whole of the devil liquor and 27 p.ct. of the spent liquor from the still. No serious trouble of any kind has arisen in the operation.

The biological purification of effluent liquors carried out on the Foleshill bacteria beds at Coventry, constructed for the purpose, has received further careful examination. The results suggest that this method is technically effective but at a heavy monetary expenditure. The cost of treatment for the period under review amounted to 11s. per ton of sulphate for the running costs, or 30s. 10d. if allowance is made for interest and depreciation.

Further inquiry has been directed into the position of processes recently proposed and under trial on large-scale plants, particularly in the bye-product coke oven industry, for the extraction of phenol, always present in effluent liquors. Dr. Monkhouse visited Germany in July, and his report on some of these plants is given. The results obtained would suggest the advisability of getting the phenol extraction process tested thoroughly under gas-works conditions, where its technical and commercial possibilities for the gas industry can be more exactly ascertained. In this connection it has to be remembered that the higher tar acids, in addition to monohydric phenols, have to be taken much more seriously into account in gas-works than in coke oven effluents, particularly where vertical retorts are employed. For this reason laboratory experiments have been conducted at Coventry in which the action of benzole and mixtures of benzole and aniline in the extraction of phenol and the higher tar acids from liquor have been subjected to examination. Interesting results have been obtained, and the laboratory experiments are to be followed up by studying the effects obtained on a semi-scale plant which has been already erected. In this plant the counter-current flow of the liquor and solvent will be adopted.

Two Phases of the Work.

Before this report was presented Prof. Cobb stressed the fact that the work of the Committee was of two kinds—investigation and individual assistance. The latter can, of course, be rendered by the investigations; but the Committee are affording help, on request, to individual gas engineers who are having

any kind of difficulty or are in any uncertainty in regard to the disposal of their effluent liquors. Mr. Botley, who then outlined the work that has been done by the Committee, made it certain that any haphazard or careless methods of disposal which may have existed in the past, or which may exist now, cannot be continued without trouble to those concerned.

The next speaker was Dr. Parker. He put forward the view that the important factor to bear in mind is that, with improved sanitation and the more cleanly habits of the people, more and more reasonably pure water is being required every year, and—

quite apart from requirements of this nature—many industries need water comparatively pure for their processes. Eventually, more and more rivers (many of which are at present to some extent polluted) will have to be used as the sources of both domestic and industrial supply. "And there is no doubt about it," said Dr. Parker, "that the work of the Effluents Committee has been extremely valuable, not only in helping the different gas undertakings, but also in helping the sewage authorities and others to understand the problem and to look at it in a reasonable manner." He believes that at the present time, for most works, the best way out of the difficulty of the disposal of effluent is to reduce the volume of the still effluent, after evaporating the devil liquor, either by spraying into chimneys or on producer bars. The remaining liquor may be put into a storage tank, so that it can be run in constant and regulated quantity into the sewers of the local sanitary authority.

Work at Manchester.

Mr. A. L. Holton indicated the lines on which the Manchester Gas Department is working. He has an experimental plant in which he is carrying out a series of experiments in arresting the tar immediately at the outlet of the retort house. For this purpose he has installed a tower packed with Raschig rings. This experiment has been in operation for only a short time, but he is regularly separating 85 p.ct. of the tar in the gas. This tower is followed by a washing tower. At present he is washing with anthracene oil, but he intends later to try both benzole and aniline.

The President suggested that a good deal might be done by controlling the temperature at the top of the retort. He looks forward to the time when someone will relate his experiences of the deliberate cracking of the tar vapours as they leave the retorts. As to evaporation, he thinks that, without special means, the majority of engineers will be unable to deal with more than 10 or 12 p.ct. of their effluent liquor in this manner.

A New Resinification Process.

The remarks of Mr. P. Parrish are full of interest. "There has," he observed, "been a good deal of fundamental work done by the Committee, but unfortunately all the processes which they have investigated do not appeal to the practical works man, inasmuch as they are likely to involve too big an expense per ton of sulphate manufactured. So far as washing gas liquor with benzole is concerned, I am afraid one cannot entertain very much hope of success there." Mr. Parrish went on to mention a method—presumably his own—which "will ensure the purification of effluent liquor at a cost of 3s. 6d. per ton." "It is," he said, "the easiest matter in the world to resinify the bulk of the phenol which the effluent liquor contains, and by mere treatment in this way to ensure resinification of the phenol and of the thiocyanates and thiosulphates. It is possible in the simplest type of plant to ensure the reduction of the oxygen-absorption figure of a phenol to such a degree as will be equivalent to domestic sewage. That matter, I understand, is to be investigated; and I know from practical experience on a large scale, that the process is capable of adoption." Mr. Botley said he had great hopes of the process mentioned by Mr. Parrish. The Committee are at present investigating it.

Following some practical observations by Mr. Mitchell, of Nelson, Dr. Monkhouse replied to the discussion, in the course of which reply he remarked that there has been a great deal of prejudice towards gas-works effluent by sewage authorities, but this is tending to change. The results of such work as that carried out at Cheltenham, which were published in the "JOURNAL," have done a great deal to lighten this problem.

Ammonia.

This brought us to the 3rd Report of the Ammonia Sub-Committee. This consists of a review by Dr. Parker of the Feld processes, an optimistic survey of the use of anhydrite in the production of ammonium sulphate by Mr. Parrish, and a report on bye-product ammonia by Dr. E. W. Smith and Mr. Hollings. Apart from the subject matter of the sectional reports, the Sub-Committee has also had before it during the year various proposals concerning ammonia production, including that of Mr. W. Wilson, of Burton-on-Trent, for the production of ammonium bicarbonate, into which inquiry has already been instituted with the assistance of Dr. Monkhouse. But more of this anon.

The Feld Processes.

We cannot do better here than quote from Dr. Parker's summary. Two processes, he states, were developed by W. Feld for the simultaneous extraction of ammonia and sulphuretted hydrogen from crude coal gas and the production of ammonium sulphate. In the first the absorption of ammonia and sulphuretted hydrogen was achieved by solutions of ferrous sulphate and thiosulphate, and regeneration of the solutions for further use was brought about by the action of sulphur dioxide and air, the sulphur dioxide being produced by the oxidation of

sulphur recovered in the process. In the second process the ammonia and sulphuretted hydrogen were removed by a solution of ammonium polythionates, and the solution was regenerated for further use by oxidation with sulphur dioxide and sulphur. In both processes various difficulties arose, partly owing to the development of troublesome side reactions which occurred in addition to the main reactions desired. Further, the processes appear to be too complex for satisfactory operation on a gas-works. In any process for the simultaneous recovery of ammonia and sulphuretted hydrogen from coal gas and the pro-

duction of ammonium sulphate, sulphuretted hydrogen must be oxidized to produce the " SO_3 " radicle to neutralize the ammonia. In the usual method of purification of coal gas, the sulphuretted hydrogen is taken up by iron oxide, and the first stage of oxidation of the sulphide to sulphur is brought about by exposure to the atmosphere. The sulphur is then further oxidized in the manufacture of sulphuric acid. One of the primary considerations in a comparison of existing practice with processes similar to those devised by Feld, therefore, is the relative cost of oxidation of sulphuretted hydrogen to the sulphate radicle, *and in this respect it appears that the Feld processes do not show any indication of offering advantages.*

The Anhydrite Process.

A considerable portion of Mr. Parrish's statement is a copy of his contribution to the World Power Fuel Conference in 1928, which was published in the " JOURNAL." In this he urged that the anhydrite process as an alternative to the use of sulphuric acid needs to be carefully considered. The nature of the process, however, necessitates a medium-sized scale of operations, and it is the view of Mr. Parrish that plant to deal with less than 30 to 40 tons of ammonium sulphate per day would not be warranted. Where the centrally situated chemical works is sufficiently large, it would, he suggests, be advisable to consider a process which involved the manufacture of diammonium phosphate and calcium nitrate from (*a*) concentrated gas liquor; (*b*) ground phosphate rock treated with sulphuric acid in the manufacture of phosphoric acid; and (*c*) the utilization of the precipitated calcium sulphate (which is really in a better form physically than anhydrite), in the production of ammonium sulphate. Incidentally, the calcium carbonate produced from the latter process could be treated with nitric acid obtained by the oxidation of ammonia (Ostwald process), to yield calcium nitrate and release carbon dioxide for the carbonatation process.

Since that contribution was made, there has been opportunity to investigate certain aspects of the production of ammonium sulphate from calcium sulphate; and says Mr. Parrish in the present report: That the production of ammonium sulphate from anhydrite may be regarded as a conventional chemical works operation is abundantly confirmed by the trials which have been conducted since the original contribution was made. Indeed, subsequent investigation has revealed that in certain respects the process can be simplified, that a higher concentration of ammonium sulphate solution, up to 40 p.ct., is possible, that filtration difficulties are not likely to arise with the Gotham quality of anhydrite, and these advantages must inevitably be reflected in reduced operating costs, below what were foreshadowed in the original contribution.

The Findings of Dr. Smith and Mr. Hollings.

At the present time Dr. Smith and Mr. Hollings cannot indicate any new research upon the subject of ammonia which the Institution can initiate with any reasonable prospect of economic advantage. It is desirable, however, that individual gas undertakings should continue to develop schemes and processes that may arise. The Committee, they suggest, should examine any new process and keep in the closest touch with all developments. For this purpose it may with advantage arrange such brief investigations as are necessary to check claims respecting new processes. In most gas-works improvements in condensation and distillation conditions represent the most useful work which may be taken in hand immediately. Consideration should be given to the organization of district co-operative schemes for the treatment of concentrated liquor; and consideration should be given to the possibility of making the gas industry self-supporting in respect of sulphuric acid.

Experiments in Progress.

The report of Dr. Smith and Mr. Hollings is concluded by a memorandum on experiments in progress in the laboratories and works of the Gas Light and Coke Company. From time to time various suggestions have been made relative to the use of ammoniacal liquor for coke quenching and to the discharge of it without treatment into waterways. The difficulties created by either of these processes might be mitigated if a process of fractional condensation was carried out, and if only the weak liquor from the condensation stage immediately following the retort house foul gas mains was used or disposed of. There would then be available for making sulphate a much smaller bulk of liquor containing most of, but not all, the original ammonia. Experiments upon the quenching of coke are proceeding.

A further means of disposal of the very weak liquor obtainable either by fractional condensation or by treatment in a still, which is under consideration consists in using it for generating steam for admission to the gas producers of the retort settings. Obviously this means is applicable to any ammoniacal liquor, but the wastage of ammonia may be minimized by selection or pre-treatment of the liquor. The quantity of water evaporated on the bars or in the pans of producers in gas-works appears to be between 10 and 20 gallons per ton of coal carbonized.

A Wise Amalgamation.

The President informed the members that the Liquor Effluents Committee and the Ammonia Committee will henceforth be amalgamated. One Committee will in future deal with the two matters.

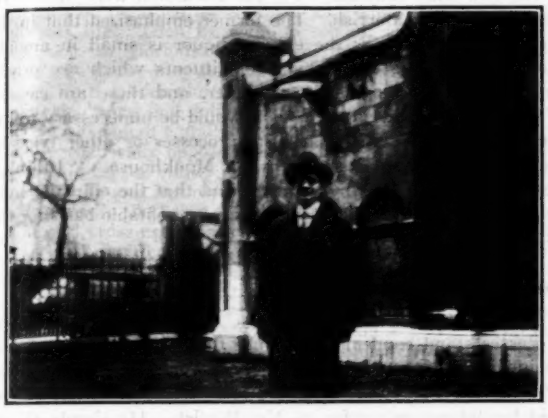
Manufacture of Ammonium Bicarbonate.

Mr. W. Wilson then interested vastly those present by an outline of what he is doing at Burton-on-Trent. He found himself in the not unusual position of getting no return for his ammonia—concentrated liquor of about 14½ p.ct. ammonia content. He decided to forget all about the " Feld fancy process," and to make ammonium bicarbonate. He installed a small compressor to deal with 10 p.ct. of the foul gas stream, and he compressed the gas into a small tower. The carbonic acid seized all the ammonia, and in three or four days salt formation set in—and the salt is 99·9 p.ct. pure. He suggests that the only disadvantage to the adoption of the process is the cost of compressing the gas; and the decision to compress all the foul gas is unquestionably formidable. But, he says, if one can make 20 lbs. of sulphate per ton of coal, one can make 34 lbs. of bicarbonate—or one ton of bicarbonate from every 65 tons of coal. This means the compression of a million c.ft. of gas; but, with coke at 2s. 6d. a ton, and free water, the fuel consumption, he states, is only 7s. 6d.—and to-day ammonium bicarbonate stands at £18 a ton. If the gas industry had to market large quantities of bicarbonate, the selling price would come down, but, thinks Mr. Wilson, not to a price at which anyone would suffer a loss on its manufacture. Moreover, there are many outlets for the salt.

In Critical Mood.

Mr. Parrish made a long speech in which he characterized the report by Mr. Hollings and Dr. Smith as an " expression of consummate wisdom." But, he said, the essential findings were summarized by himself in 1925; and it is to be deprecated that the gas industry did not act sooner in the matter. Something of the order of £500,000 a year is now being lost; and this might have been avoided had there been prompt and combined action four years ago. He urged that improvements should be effected in the design and operation of concentrated gas liquor plants; and he mentioned that he had designed a plant so simple to operate that it was possible to work the plant without labour. In regard to the recommendation that the gas industry should be self-supporting in respect of sulphuric acid, he called attention to the variation in demand throughout the year. " Where a sulphuric acid works is erected primarily to supply gas-works needs . . . it is impossible to operate advantageously where the demand for sulphuric acid arises almost exclusively from gas-works. On the other hand, at a centrally situated chemical works it will be possible to provide more modern and more efficient sulphuric acid plant than generally exists in this country to-day." Mr. Parrish went on to say that what the gas undertakings have failed to do in this matter is to act in a resolute way. " With a knowledge of all the circumstances, with an appreciation of the fact that the gas industry can ally itself to another important industry, it would be easily possible to establish centrally situated chemical works throughout the country to advantage. Such works should be capable of absorbing, or disposing of, to a large extent, the production of ammonium

sulphate, or mono-ammonium phosphate, or di-ammonium phosphate, or calcium nitrate, or double superphosphate, or other compound fertilizer products." As to the bicarbonate process, Mr. Parrish is of opinion that it would be impossible to convert the whole of the bye-product ammonia in this country into bicarbonate, as no market exists for such a quantity. The process might prove economically sound as an ammonia concentration one, but many aspects of the matter need further investigation—particularly the question of the costs of compression, and whether this is really necessary. Finally, Mr. Parrish suggested that the problem of bye-product ammonia has been discussed sufficiently. It is now time for resolute and determined action on sound and approved lines.



Ammonia Recovery at Stretford.

Col. W. M. Carr commented on the statement by Mr. Hollings that, because of the deficiency of carbon dioxide, the virgin liquor obtained from horizontal retort gas by the method of fractional condensation is a less efficient washing medium than that obtained from vertical retort gas. Col. Carr expressed the hope that this statement will not create a general impression that ammonia cannot be efficiently and effectively scrubbed from horizontal retort gas by the use of cool virgin liquor of low free ammonia content. At the Stretford Gas-Works the whole of the straight coal gas is produced in horizontal retorts, and no water is used for the extraction of ammonia, nor is any difficulty experienced in obtaining complete extraction, leaving an ammonia content at the outlet of the washer of from 3 to 5 grains per 100 c.ft.—the desired quantity to keep the purifiers alkaline. The Stretford plant lends itself to the adoption of fixed ammonia washing in that the retorts are equipped with Congdon standpipes. Liquor is taken at the outlet of the Congdon circulating pumps, and is cooled to a temperature of 60°-62° F. maximum in a suitable water cooler of the type commonly in use in conjunction with the dry gas process. The free ammonia washing liquor, and gas, entering the washer are both at approximately the same temperature—60° F. The process, said Col. Carr, has proved entirely successful, a liquor of 14-oz. strength being obtained.

Attention was called by Mr. Wilton to a process which has been developed by the Chemical Engineering and Wilton's Patent Furnace Company for the recovery of sulphur dioxide from flue gases. "Probably the cost of the sulphuric acid as a result of this process," said Mr. Wilton, "will be reduced considerably, sufficiently to alter the whole aspect of sulphate of ammonia production." Mr. A. L. Holton, who makes sulphuric acid, emphasized that, if gas engineers wish to obtain a good price for their spent oxide they should not put into it products which add to the cost of making sulphuric acid.

The Power of the Gas Industry.

In his reply, Dr. Smith suggested that Mr. Wilson was in error in thinking it practicable for the industry to put on the market the equivalent of nearly 200,000 tons of ammonium bicarbonate per annum, because "there is not a market for anything like this quantity, not a fraction of it." Mr. Wilson's work, however, said Dr. Smith, "is a really valuable addition to the technique and the possibilities of handling concentrated ammonia." He endorsed the idea of Mr. Parrish that, as an industry, we should recognize our strength. Undertakings should, if necessary, work together as an industry, economically and financially in some respects; and on no account should the concentration of ammonia be allowed to pass out of the control of the gas industry. In reply to Mr. Parrish, Dr. Smith pointed out that Mr. Hollings' report was only a summary of the work of others.

Gas Fellowship Report.

This brought us to the 1929-30 Gas Fellowship Report, the Research Fellow this year being Mr. A. H. Eastwood. The work described in the report constitutes another stage in an investigation commenced some years ago at Leeds into the liberation of nitrogen and sulphur under varied conditions during the carbonization or gasification of coal. A fusible coal (Sharlston Wallsend, Haigh Moor Seam) containing only 1 p.ct. of ash was taken, and to it additions of three ash constituents were made. The pure coal and the mixtures were carbonized in atmospheres of nitrogen, hydrogen, and a steam-nitrogen mixture containing 60 p.ct. of steam. The total time of carbonization was 9 hours, the temperature being advanced in stages of 100° C. from 200° to 1000° C. With the pure coal, in all cases ammonia evolution commences at 300° C. and reaches a maximum at 700° C. The maximum of 700° C. is very marked, and little ammonia (except in hydrogen) is obtained above it, partly owing to thermal decomposition and partly to the fact that the bulk of the nitrogen which can be obtained as ammonia by the action of heat alone has already been driven off. In a neutral atmosphere (nitrogen) carbonization up to 1000° C. yields 17 p.ct. of the nitrogen of the coal as ammonia. Substitution of hydrogen for the nitrogen results in an approximately doubled yield, 33·3 p.ct. of the nitrogen now being obtained as ammonia. Substantial equivalence exists between the extra ammonia formed and the increase in the quantity of nitrogen lost by the coke. Hydrogen does not reduce the loss of nitrogen in forms other than ammonia.

The use of an atmosphere of steam and nitrogen containing 60 p.ct. steam gives a yield of ammonia equivalent to 25 p.ct. of the nitrogen of the coal. In this atmosphere the loss of nitrogen from the coke in forms other than ammonia is also increased. In no case is all the nitrogen of the coal liberated obtained as ammonia, and it would seem that it is impracticable to obtain it all in this form.

Considering the mode of formation of the ammonia it would seem that this takes place in two ways:

(1) By the decomposition of some nitrogen compound or compounds, probably mainly ulmic, under the influence of heat. This decomposition commences at 300° C. and gives its maximum yield at 700° C. Hydrogen or steam do not appear to affect it apart from exercising a protective action on the ammonia formed.

(2) By the action of hydrogen on some nitrogen compound

in the coke. This reaction does not occur at or below 500° C. The nitrogen gasified in this manner is all liberated as ammonia, although some of this ammonia may be afterwards lost by thermal decomposition. The nitrogen compounds decomposed by this reaction may be present in the original coal, but it is more probable that they are formed during carbonization. They are found to be stable up to 800° C. in a neutral atmosphere (nitrogen).

With these mixtures of coal and added inorganic constituents, ammonia evolution again commences, in all cases, at 300° C., and reaches a maximum, in all cases except one (iron oxide coal in nitrogen), at 700° C. In a neutral atmosphere (nitrogen) the addition of lime or calcium carbonate raises the ammonia obtained up to 1000° C., expressed as a percentage of the nitrogen of the coal, from 17 to 22 p.ct., while iron oxide decreases the yield to 15 p.ct., there being a marked diminution from 700° C. upwards. The addition of crushed pure coke shows no effect on the ammonia yield. In hydrogen the high yield of 33 p.ct. obtained from the pure coal is raised to 37 p.ct., about the same increase as in nitrogen, by the addition of calcium carbonate. Lime gives a slightly less increase, while iron oxide has no effect, the marked diminution at 700° C. and upwards, noted in the nitrogen atmosphere, not occurring. In the mixture of 60 p.ct. steam and 40 p.ct. nitrogen, lime raises the yield from 25 to 34 p.ct., calcium carbonate to 32 p.ct., while iron oxide perhaps raises it slightly, the diminution from 700° C. upwards being again eliminated.

Ammonia Reduction?

There was not much discussion on this report. Mr. Madden, while thanking Prof. Cobb and his staff on the work they have done, suggested that under present conditions it might be a good thing to reduce, rather than to increase, the production of ammonia from a ton of coal. In this connection, Dr. Parker said that we had to get rid of ammoniacal liquor—not ammonia; and if we must have the former, we might as well have as much ammonia in it as possible, in order to decrease the cost of distillation of the liquor per ton of ammonium sulphate produced. Prof. Cobb called attention to a sentence in the 3rd Ammonia Report: "It is sometimes erroneously supposed that because the manufacture of sulphate represents a loss, then it is advantageous to have a low yield of ammonia from the gas-works." He also observed that the Fellowship Report forms part of a systematic study of a fundamental nature—a study which, he believes, has been well worth carrying out. Dr. Monkhouse suggested that the report is a stage towards the elucidation of the constitution of coal.

Direct, Semi-Direct, and Indirect.

Discussion on the Second Report of the Ammonia Committee was taken next. This report, by Dr. Parker, concerns the direct, semi-direct, and indirect systems of ammonia recovery, and was published in the "JOURNAL" in November, 1929.

Dr. Parker remarked that in the direct and semi-direct processes tar must be more efficiently removed from the hot gas than in the indirect process, and the cost of this must be put on to the cost of the process, unless for some reason connected with the disposal of effluent liquor the tar must be removed from the hot gas to improve the quality of the effluent. It should also be remembered in comparing these processes that the indirect process can be run with a stronger liquor than is usual at the present time by avoiding the use of water in the scrubbers.

The two other contributors to the discussion were Mr. C. H. Sensicle and Mr. Parrish. The former emphasized that in the direct recovery process the effluent liquor is small in amount and contains oxygen-absorbing constituents which are practically completely phenolic in character, and these are capable of extraction by solvents. Thus it would be unnecessary to use methods of oxidation by bacterial processes or other types of plants that have been described by Dr. Monkhouse. "I think," he said, "that eventually we shall find that the effluents from this type of plant will be worked up on a profitable basis for the extraction of monohydric phenols."

For the Indirect Process.

Mr. Parrish maintains that the semi-direct and the direct processes stand condemned because they are incapable of producing ammonium sulphate of the quality that can be produced by the indirect process. Replying to the discussion, Dr. Parker said he did not go so far as Mr. Parrish. He simply thinks that there is no decided financial advantage in adopting the direct or semi-direct process over the indirect.

On General Topics.

Mr. A. L. Holton, at this stage, put forward the view that the discussions of reports would be freer and better if they were not reported in the Press. The President, however, reminded him that the meeting represented only a small part of the industry, and it is through the Press that the industry meets the public. Mr. T. F. E. Rhead then remarked that the reports savoured too much of lectures; while another member put in a plea for the earlier circulation of the reports. "I received," he observed, "300 or 400 pages of printed matter about an hour before I got into the train for this meeting; and under these conditions one cannot be expected to take a reasonable part in the discussion."

Next Annual Meeting.

The President announced that the next annual general meeting of the Institution will be held in London on June 2, 3, and 4, 1931. This will be more or less in the nature of an international conference, and it is likely to be one of the most important meetings of the Institution ever held.

An omnibus vote of thanks concluded the proceedings.

Luncheon to the Research Workers

At the Savoy Hotel, on Tuesday, a largely attended luncheon was given by the President (Mr. Harold E. Copp), who was in the chair, and Council to those associated with the research work of the Institution of Gas Engineers.

Mr. J. F. RONCA (Director of Gas Administration, Board of Trade), proposing the toast of "The Institution of Gas Engineers," expressed his keen appreciation of the honour that had been done him in asking him to do so. He had to confess that his conception of engineers had undergone various changes. As a youth he regarded an engineer as a kind of god who lived a glorious life. Then he went to school, and the engineer did not look so glorious. At college he learned that engineers were not gods—they had to do work and make it pay. Still later, he had seen the engineer in another capacity, as a cold and calculating and deliberate exponent of the law, opposed by another exponent equally calculating and equally deliberate; the one diametrically opposed to the other. The one presented his case with crystal clarity, and the other presented his with cogent conviction; and in order to prove his statements, the engineer was put into the firing trench, and had to stand up to examination and cross-examination. The engineer was nothing like a god. [Laughter.] If one's ideas about engineers changed, one's other ideas changed also. They all realized that they were not going to find satisfaction in idleness, but in work. The Institution had recently been granted a Royal Charter, and its members were taking the most energetic steps to look after the training of their successors. Their autumn research meeting was a more or less outward sign of the active interest they took in research. He had read three of the reports presented to that meeting. The first dealt with the corrosion of pipes—that was an electrical paper. The next dealt with ammonia—that was a chemical paper. The third dealt with the products of combustion from gas appliances—that was a combined physical and chemical paper. Their interests were therefore very widely spread. Gas engineers, being capable of judging men, had systematically chosen as Presidents of the Institution men of considerable energy, and as a result the Institution was a very active and live one.

The PRESIDENT (who was received with applause on rising to respond to the toast) remarked that the autumn conference of the Institution was inaugurated by his predecessor, Mr. Shapley, last year; and the proceedings at that conference were so satisfactory to everyone who participated in them that it seemed to him (the speaker) that there was nothing else to do but to carry on with that precedent. He thought that the excellent attendance and the first-rate reports and discussions they had had that morning had already amply justified this decision. ["Hear, hear."] Their annual conference in London next June was to have a somewhat international character, in that they had asked representatives from about 16 kindred associations in other lands to come and participate in their proceedings, and from the replies they had had up to now they were greatly encouraged, and believed the meeting would really be of an international character. This would be all to the good, because knowledge of what was being done in other countries must necessarily broaden their minds. The Institution was certainly an active one, and he thought the proceedings at that meeting would prove that the members were enthusiasts. Anybody who was going to do an industry any good must be an enthusiast.

Mr. J. TERRACE submitted the toast of "Our Guests," and declared that the Institution was justly proud of its research work. That work was started 23 years ago, and he thought they had to their credit a very satisfactory record. The information obtained on many subjects would always be available, and was very valuable to those who required it. Under the urge of the energetic Chairman of the Research Committee, Mr. T. Hardie, they were going still further with work which must be of great use to the industry. He did hope that in the future they would be able to have some more tests made on the Corbet-Woodall carbonizing plant at Leeds University, and if they could not find out things they could do, then find out some things they could not do. Prof. Smithells had been asked to respond to the toast because of his association, from the inception of the investigations, with the research side of the Institution. His research work in connection with the gas industry was perfectly well known to all. They appreciated, and were grateful for, the services which Prof. Smithells had rendered to the industry in many directions.

Prof. ARTHUR SMITHELLS, responding to the toast, said that the kindness of the Institution had been so great and so frequent that, although gratefully acknowledging himself their guest, he could not feel otherwise than at home at any of their meetings. The work that he did in his early days would have gone a very little way had it not been for the great men with whom he was associated—George Livesey and Corbet Woodall. The members could imagine what it had meant to him to watch events since then, and to be at a meeting such as the present one, devoted wholly to research in regard to problems with which they were confronted to-day. He felt very appreciative of the response that had been made by the gas industry to the approach of Science. He had been exceedingly proud of the position taken by his old University, and of the great body of investigators who were now at work trying to solve the problems facing the gas industry. He was delighted to see the progress made in the organization of the work in every respect, and he was particularly pleased to see how the subject of research was now dealt with by the Institution so far as meetings were concerned. Mr. Terrace himself had laboured hard in this connection. It seemed to him that the meeting last year under the Presidency of his old friend Mr. Shapley, of Leeds, which was being succeeded to-day under the firm but kindly guidance of Mr. Copp, showed a very great improvement. The presentation of the research results involved great difficulties to all concerned, but they had learned a good deal and they were learning more, so they had got to a much better condition. They were always moving forward, and it had been a continuous delight to see the progress made—the continued *rapprochement* between Science and Industry, which was not excelled, he believed, in any other industry in the country. He had always been averse to State intervention in the industrial world, but in great questions such as Fuel there was need and opportunity for the State to bestir itself. It had done so by putting up an organization, the Fuel Research Board, with which the industry worked in perfect harmony, and with great benefit. With Dr. Lander, and those associated with him, they worked side by side. But he still thought it right that the individual industries should look after themselves, and he was happy to think that the Institution of Gas Engineers was setting so good an example. He would like to pay his tribute to their excellent research workers.

At the call of Sir DAVID MILNE-WATSON, the health of the President was enthusiastically drunk. "We all look upon the President," said Sir David, "as one of the leaders of the industry, and we delight to see him in the position he occupies to-day. We wish him health and happiness through his year of office."

Final Meeting of the Old Institution of Gas Engineers

Before the Special General Meeting was resumed on Wednesday, Nov. 26, there was a meeting of the old Institution of Gas Engineers (Incorporated under the Companies Acts in 1902) to receive an account from the Liquidator (Mr. J. R. W. Alexander) as to the winding-up of this Institution which has been superseded by the new Institution of Gas Engineers (Incorporated by Royal Charter in 1929).

Mr. ALEXANDER said: At a Special General Meeting in June last of the Institution of Gas Engineers, incorporated under the Companies Acts in 1902, of which all members of that Institution had notice, a formal resolution was passed to "wind up" its affairs, and I was appointed Liquidator. To-day's meeting is held to receive the Liquidator's report, due notice having been given in the "London Gazette."

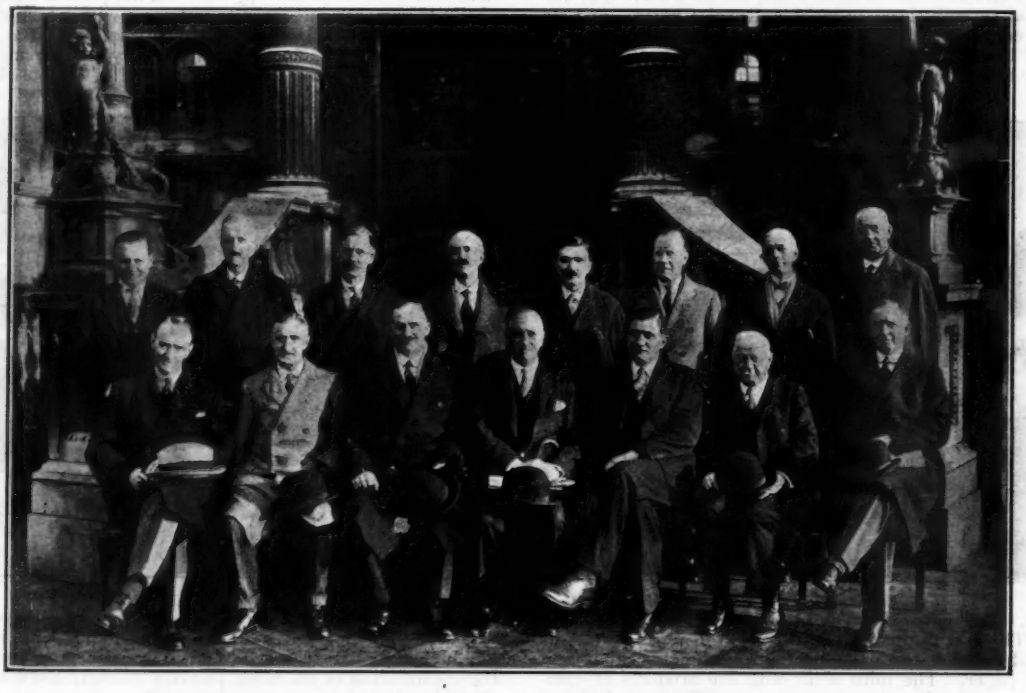
My report is a short one, and consists merely of stating that the legal formalities have been complied with and that the old Institution has paid its debts and met such of its obligations as have not been transferred, together with the assets, to the new Institution, which was incorporated by Royal Charter on May 23, 1929, to take its place.

Thus, gentlemen, the old Institution brings an honourable career of twenty-eight years to an end—a career which has been marked by considerable progress in the gas industry and substantial advancement in the prestige and status of the gas engineer, for both of which the Institution and its members were chiefly responsible. Moreover, this old Institution has made itself the more remarkable by combining with its decease the birth of a lusty infant, the Chartered Institution of Gas Engineers—an infant which, judging from its distinct achievements of the first eighteen months, will pay its distinguished parent the greatest compliment of all, that of attaining even greater eminence than its progenitor.

In bidding farewell to the old Institution, it is appropriate to observe that it was the result of an opportune amalgamation of the two bodies which had represented the industry and the profession during the eleven years from 1891 to 1902. These two bodies had arisen owing to internal dissension, the industry and the profession having been represented during the previous twenty-eight years (1863 to 1891) by the British Association of Gas Managers, afterwards known as the Gas Institute. It will thus be seen that the present Institution had its origin sixty-seven years ago, the year 1863 being sixty-one years after William Murdoch first lit a works with gas, and twenty-three years before incandescent lighting was invented. Few professional bodies in active existence to-day can claim a longer history.

This will probably be the only occasion upon which I shall be privileged to occupy the chair at a meeting of the Institution of Gas Engineers, and you will, perhaps, permit me to perform the last rites in the passing of the Old Institution, by referring to the future. Wise men there are who, while acknowledging the service of the industry to the common weal in the past, wag their heads as to the future and express the conviction that the gas industry must inevitably decline. Apart from drawing attention to the uncanny regularity with which such folk receive their dividends, and to the capital which the industry is so readily able to command, the best answer, since it is unbiassed, to such criticism is to be found in the Board of Trade Returns. Those for last year show an increased sale of gas of 3·6 p.ct., which is equivalent to the output of Glasgow or the combined sales of Leicester and Liverpool. More gas has been sold per consumer, and, in spite of bad trade and unemployment, the addition of a quarter-of-a-million consumers in 1929 brought the total figure to over nine millions.

Competition acts as a stimulus, and has been turned to good account by the gas industry, which during the course of the past one hundred and twenty years has learnt, what others have yet to learn, what a fickle jade is fashion and what an ever-encroaching octopus is State aid.



MEMBERS OF THE INSTITUTION COUNCIL.

The PRESIDENT: I am sure we have all enjoyed listening to the Liquidator's report. He is full of optimism, and I think we need not feel any sadness at the obsequies of the old Institution. We may look forward, I am sure, with hope and confidence to the future. I myself am a great believer in the future of the gas industry. I also think that we are very fortunate in possessing such an energetic and capable Secretary as Mr. Alexander. Further than that, we are very fortunate in the fact that, being a barrister, he has been in the position of being able to act as Liquidator. I think he has performed the whole of the duties in a very satisfactory manner, and we are very much indebted to him. I will now formally move the acceptance of the Liquidator's Report to the effect that the old Institution be wound up and the new one takes its place and assumes all the responsibilities of the old Institution.

Mr. W. E. PRICE (Hon. Secretary): I have much pleasure in seconding that proposition as one who has had a little to do with both Institutions in keeping alive the old one and also taking some part in the birth of the new one, a sort of midwife. I have much pleasure in seconding the motion; it is a case, I think, of "The Institution is dead, long live the Institution."

The PRESIDENT then put the resolution to the meeting, and it was carried unanimously.

Continuing, he said: I wish to express our gratitude to Mr. Shrimpton for the assistance he has given us throughout on this matter.

Mr. SHRIMPTON expressed his thanks.

REPORTS AND DISCUSSIONS - -

Most of the Reports have necessarily been Abstracted.

1st Report of the General Research Committee 1929-30

The Report covers the year 1929-30, during which period the members of the Committee were: Charles S. Shapley (Chairman), Thomas Hardie (Vice-Chairman), Charles F. Botley, J. H. Canning, Dr. Charles Carpenter, Prof. J. W. Cobb, Dr. H. G. Colman, Harold E. Copp, E. V. Evans, W. Doig Gibb, Samuel Glover, Thomas Glover, F. Harding Jones, Stephen Lacey, Dr. C. H. Lander, J. W. McLusky, P. G. G. Moon, J. W. Napier, W. E. Price, T. F. E. Rhead, Dr. E. W. Smith, W. J. Smith, Prof. Arthur Smithells, Albert Stokes, Samuel Tagg, John Terrace, and Henry Woodall.

The General Research Committee seeks to supervise and co-ordinate the research work of the Institution of Gas Engineers, and particularly that of (*a*) the Joint Research Committee of the Institution and Leeds University and (*b*) the Research Sub-Committees of the General Research Committee. Subject to the Council of the Institution, it directs what research work shall be done, recommends what financial appropriations shall be made therefor, and is responsible for the appointment of the Research Chemists, Assistants and Staff. It works in co-operation with the Livesey Professor of Coal Gas and Fuel Industries at the University of Leeds. Research Reports are made to the General Research Committee by the Joint Research Committee and the Sub-Committees and by the Institution Gas Research Fellow as to his year's work at Leeds University. These Reports are submitted by the General Research Committee to the Council for presentation to and discussion by the Members of the Institution in General Meeting, after which they are incorporated in the yearly Transactions of the Institution.

It is appropriate, therefore, that this Report to the Council should deal with the work of the General Research Committee under the headings of the Joint Research Committee, the Sub-Committees and the Fellowship, and that Reports which cannot be conveniently reproduced in full herein should be published separately.

Joint Research Committee of the Institution and Leeds University.

Three Reports, each published separately, are made to the General Research Committee by the Joint Research Committee of the Institution and Leeds University as to its work during 1929-30, viz. :—

25th Report: " Examination of the Products of Combustion from Typical Gas Appliances—Part V."

26th Report: " 2nd Report on the Use of Creosote in the Manufacture of Carburetted Water Gas."

27th Report: " 1st Report on the Back-run Process for the Manufacture of Carburetted Water Gas."

The *25th Report* of the Joint Research Committee gives an account of the continuation of the investigation of the output of carbon-monoxide by typical gas appliances. The results obtained with a surface combustion water-heater show remarkably small amounts of CO if the excess of air in the combustible mixture is 10 to 15 per cent. of the theoretical requirement. Tests with the special burner of the Fairweather Recording Gas Calorimeter show that there is no appreciable loss of the heating value of the gas due to imperfect combustion.

The principal item in the Report is the investigation of the inverted incandescent burner. The mere inversion of the flame produces rather more CO than is given by the upright Bunsen burner, but the amounts are still negligibly small. When a mantle is placed in position the CO production rises appreciably and the gas-rate-CO production curves assume a characteristic U-shape. Over the normal working range of the burner (4 to 5·5 c.ft. per hour) the CO production is very low, only 10 to 20 parts of CO per 10,000 of gas burned. If the gas-rate is considerably increased, even up to 8 c.ft. per hour, there is only a small increase in CO production. On the other hand, if the burner is turned down, CO production increases rapidly, and it is recommended that burners should not be used under such conditions.

The Report concludes with a review of some features of the design of continental gas appliances, as shown at the Berlin Gas and Water Exhibition in 1929 and an account of the examination of the fumes of domestic burners by a pyrographic method.

The *26th Report* of the Joint Research Committee is a concise statement of the results of a laboratory investigation of the possibilities of using creosote in the manufacture of carburetted water gas. The present results indicate that the use of creosote for carburetted water gas manufacture are not promising. The investigation is being continued and a further report will be made.

The *27th Report* of the Joint Research Committee describes a complete test of the back-run carburetted water gas plant at the Stratford Works of the Gas Light and Coke Company. This is the first stage of an investigation into the influences of the back-run, self-clinkering grate, and various other recent modifications in the design of carburetted water gas plants. The investigation will be continued at the Nine Elms Works of the Company, where it will be possible to compare the efficiencies of the plant when operated with and without back-run steaming.

Ammonia Sub-Committee.

The 3rd Report of the Ammonia Sub-Committee is published separately, and includes (*a*) " The Feld Processes for the Extraction of Ammonia and Sulphuretted Hydrogen from Coal Gas," by Dr. A. Parker; (*b*) " The Use of Anhydrite (Calcium Sulphate) in the Production of Ammonium Sulphate," by Mr. P. Parrish; and (*c*) " By-Product Ammonia," by Mr. H. Hollings and Dr. E. W. Smith.

In preparing " By-Product Ammonia " the authors reviewed the remainder of the present Report and the previous Reports of the Ammonia Sub-Committee, and concluded that at the present time they cannot indicate any new research upon ammonia which the Institution can initiate with any reasonable prospect of economic advantage. It would be desirable that individual gas undertakings should continue to develop schemes and processes that may arise, and the Sub-Committee could examine any new process brought to its notice and keep in the closest

touch with all developments. Improvements in condensation and distillation conditions should be undertaken by most gas-works. Consideration should be given, the authors conclude, to the organization of district co-operative schemes for the treatment of concentrated liquor and to the possibility of making the gas industry self-supporting in respect of sulphuric acid.

The General Research Committee has recommended the Council to amalgamate the Ammonia Sub-Committee and the Liquor Effluents Sub-Committee in order to facilitate the work of both.

Calorimeters Sub-Committee.

The Calorimeters Sub-Committee elected for 1929-30 consisted of :—P. G. G. Moon (*Chairman*), J. Ferguson Bell, T. Carmichael, E. V. Evans, H. H. Gracie, Thomas Hardie, H. Hollings, H. D. Madden, W. E. Price, J. D. Smith, W. J. Smith, Samuel Tagg, and John Terrace.

Careful consideration has been given by the Calorimeters Sub-Committee to the investigation which it conducted to ascertain the experiences of users of recording calorimeters. An interim report was prepared for the information of the Sub-Committee, but it is not being published, since it is hoped that adequate information will be obtained of different types of instruments so that a comprehensive Report can be presented for the guidance of Gas Engineers.

Corrosion of Pipes Sub-Committee.

The 1st Report of the Corrosion of Pipes Sub-Committee relates to "The Protection of Pipes against External Corrosion," and is published separately. It deals chiefly with the efficacy of paint as a protective coating for tubes against corrosion, and data are given of experimental methods used to determine the penetration of the coating by water. Although the available information does not at present permit of a Specification for protective coatings, the investigation has had important results and is being proceeded with.

The Sub-Committee has revised the List of Approved Makers of Wrought Iron Strip in accordance with the Wrought Iron Specifications of the Institution, which were reprinted and issued with the revised List on September 17th, 1930.

Gasholders Sub-Committee.

The Gasholders Sub-Committee elected for 1929-30 consisted of :—W. Doig Gibb (*Chairman*), H. D. Madden, W. E. Price, C. S. Shapley, W. J. Smith, J. M. Campbell, T. Carmichael, Thomas Hardie, and H. C. Smith.

The necessity for the periodical inspection and maintenance of gasholders has received the consideration of the Gasholders Sub-Committee, and, on its recommendation, the Council has addressed a letter to members of the Institution inviting their co-operation in this respect and in the keeping of a systematic record of the date, nature, and result of the inspections made and the work carried out on each holder. The question of giving detailed guidance to Gas Engineers did not appear practicable, but is being further considered by the Sub-Committee.

Liquor Effluents Sub-Committee.

The 5th Report of the Liquor Effluents Sub-Committee embodies "The Disposal of Liquor Effluents from Gas-Works" and "Phenol Recovery Plants in Germany," and is published separately.

The first part of the Report is a continuation of the 3rd Report of the Sub-Committee and deals with experiments made with a Lodge Cottrell electrostatic tar precipitator at Hinckley, and also with a cyclone tar extractor at the Foleshill Gas-Works at Coventry, to reduce the higher tar acid content of the ammonia liquor. Satisfactory results have been obtained. The evaporation of effluent liquor on the bars of the producer has been investigated, and the recent results of the biological purification of spent liquor at Coventry are recorded.

The question of the recovery of phenol from ammonia liquor has been investigated in the laboratory, whilst large scale plants in operation in Germany have been inspected by Dr. A. C. Monkhouse, whose observations are contained in the second part of the Report.

Purifiers Sub-Committee.

The Purifiers Sub-Committee elected for 1929-30 consisted of :—Charles S. Shapley (*Chairman*), J. E. Blundell, T. Carmichael, J. Foster, J. W. Napier, and F. P. Tarratt.

As the result of an extensive investigation by the Purifiers Sub-Committee into the precautions taken by undertakings to avoid explosions and fires, much valuable information has been obtained concerning the methods employed and the number and nature of the explosions, fires and personal injuries sustained. Although the corrected figures are not yet available, the investigation has demonstrated beyond doubt that proper precautions are being taken and that the number of accidents is relatively negligible.

Refractory Materials Joint Sub-Committee.

The 21st Report of the Refractory Materials Joint Sub-Committee for 1929-30 is published separately. It summarizes those investigations of the British Refractories Research Association during the year which have a direct bearing on the gas industry—several having been initiated by the Sub-Committee—and contains Mr. A. T. Green's Paper on "Observations on the Behaviour of Refractory Materials in Continuous Vertical Retorts." Work on cements for fireclay and silica products and on hot-patching cements has been continued, and the problem of the "permeability" of refractory materials is being studied.

Institution Gas Research Fellowship.

The Research Fellow (Mr. A. H. Eastwood) and the Livesey Professor (Professor John W. Cobb), in the separately published Institution Gas Research Fellowship Report for 1929-30, deal with "The Influence of the Inorganic Constituents in the Carbonization and Gasification of Coal; The Liberation of Ammonia."

The work described in the Report aims at supplementing information already forthcoming from similar experiments made in previous years, but has special regard to the influence of inorganic substances such as may occur in ash of coals, upon the evolution and ultimate yield of ammonia. In the course of the experiments it became clear how very pronounced is the maximum point for ammonia evolution at a temperature near 700° C., this being only materially disturbed by the presence of oxide of iron.

The President : It is my pleasure to present to you this first Report of the General Research Committee for the year 1929-30, of which you have copies. I should like first of all to pay a very great tribute to Prof. Cobb and his staff at the Leeds University. No matter what the critics may say as to the work which has been accomplished by the Research Committee on previous occasions, I feel sure that they will be generous on this occasion, because some very solid work has been accomplished during the past year—work which will bear good fruit for the industry in the future.

I do not propose to refer to every detail in the report, but should like to mention the use of creosote in the manufacture of carburetted water gas. That is a piece of research work which is now proceeding, and I have every hope that something will be discovered which will enable us to use creosote, the market for which is at the moment very unprofitable. There are great difficulties to be encountered in connection with the proper use of creosote for the purpose mentioned in the report.

Very valuable research has been carried out in the investigation of the inverted incandescent burner. You will notice that carbon monoxide has been taken as an index of the efficiency of the combustion of the inverted burner, and the report contains detailed figures concerning the production of carbon monoxide. It must be remembered, of course, that not only is carbon monoxide an objectionable product of incomplete production, but that, if we get high percentages of carbon monoxide, we shall also produce something else which is almost equally objectionable. The problem of the production of carbon monoxide has been concentrated upon because of the toxic nature of this constituent.

With regard to the investigation of the back-run carburetted water gas plant, which was also a research very much to be desired, I should like to express our thanks once more to the Gas Light and Coke Company for permitting the investigation to be conducted at its Nine Elms Works.

You will notice that the Ammonia Sub-Committee appeals to individual gas undertakings to develop schemes and processes for dealing with any difficulties that may arise. I think that is one of the things that we gas undertakings cannot leave entirely to other people. We have to overcome our difficulties as they arise, and we must not leave their investigation too much to an Investigation Committee.

The Calorimeter Sub-Committee has issued an Interim Re-

port, and I think that useful information has now been gleaned as to the value of calorimeters. I am quite sure that before very long we shall have an instrument upon which we shall be able to rely thoroughly.

The Corrosion of Pipes Sub-Committee has also carried out some very interesting research, and has deduced some very useful information from it. With regard to the work of the gasholders Sub-Committee, the Institution has appealed to all members to keep systematic records of their holders. This is another matter which we cannot leave entirely to a Committee. It seems to me that every engineer should systematically inspect and look after his holders with a view to the prevention of accidents, and also should keep very careful records, so that eventually the Committee may co-ordinate the information obtained by the engineers.

We should also express our thanks to the gentlemen who have given facilities for the Liquor Effluents Sub-Committee to carry out its work. It has accomplished some very useful work and has made possible the disposal of effluents which previously would have handicapped operations very much.

The matters referred to in this report are dealt with in detail in the separate reports which are to be presented to you later. Probably you would prefer to discuss these matters as the separate reports are presented; but this first report is open for discussion, if you care to discuss it.

DISCUSSION.

Mr. WALTER T. DUNN: I think the members of the Institution all appreciate that the person who should receive acknowledgment in connection with this matter is Mr. John Terrace, and I would like to express our thanks to him. We are likely to forget those pioneers who make important suggestions for the improvement of an organization. The Institution is very rich in its friends. This morning we have heard of further endowments, and when we think of endowments we have always in mind what we owe to the late Sir Corbet Woodall. I need only refer in this connection to the Corbet Woodall Scholarship and to the experimental plant erected to the memory of Sir Corbet Woodall at Leeds University. From the reports which the Institution has received, we know that great good has been done in consequence of these endowments.

With regard to other matters mentioned in the First Report, I should like to refer to the question of gasholders. The members of the Institution, in their travels abroad, will have noticed that the waterless holder is now coming very much into fashion, and fortunately—I know you will pardon my saying this—more attention is being given to the æsthetic aspect of gasholder construction. Holders are always visible to the eye, and the colouring is usually selected to harmonize with the characteristics of the surrounding landscapes. This is a matter to be remembered in connection with gasholders, and the Committee dealing with this matter will no doubt take into consideration the fact that waterless gasholders generally require less attention in their upkeep than do the ordinary holders to which we have been accustomed.

I should like also to refer to the problem of liquor effluents. I know very well that fishermen are agitating and approaching the Government with a view to the prevention of the pollution of their streams, and I hope that the Committee will consider, from that point of view, not only the effluents which discharge into the streams but those which discharge into the sea. We know there are certain works adjoining sea fronts, and there are seaside towns where, unfortunately, the effluents are discharged into the sea, with the result that complaints are made by local people. The complaints made by fishermen do not help to popularize gas, and we want to do all we can to make it popular. Mr. C. F. Botley is a pioneer in this matter.

Mr. C. S. SHAPLEY (Past President): I think that too much stress has been laid upon damage done to fish by effluent discharge. I should not like it to go forth that at this research meeting we viewed this particular subject with alarm, because, as the result of the research we have carried out, I think we can be practically certain that damage to fish life by discharges of effluents or other discharges from gas-works is negligible. A friend of mine living in the Manchester district has referred to the damage done to fish, and the resulting scarcity of fish, in Lake Windermere. There are no gas-works at Windermere, however, and the damage to fish is probably due to the noise caused by motor boats now roaming about the lake, or probably to explosions or to the deposit of oil in the Lake itself. It is not only gas-works that pollute streams, and it is not tar that pollutes streams, and we do not want it to go forward from this meeting that we are in any way alarmed. With regard to tar washings from roads, I would point out that the percentage of roads abutting on fishing rivers is about 2½ or 3 of the total. Having regard to the enormous amount of tar which is being used at present, and the enormous amount which we hope will be used in the future, to the exclusion of bitumen, for road purposes, I hope that stress will not be placed upon this bogey of the destruction of fish life.

General Introduction to the 25th, 26th, and 27th Reports of the Joint Research Committee.

By the Livesey Professor (JOHN W. COBB, C.B.E., B.Sc., F.I.C.).

The members of the Joint Research Committee for 1929-30 and of its Research Staff at the date of this Report were: Chairman: Thomas Hardie, M.Inst.C.E., M.Inst.Gas E. Representatives of the Institution of Gas Engineers: C. F. Botley, M.Inst.C.E., H. E. Copp, M.Inst.C.E., C. S. Shapley, M.I.Mech.E. (Co-opted Member for the purpose and period of research work at the Leeds Gas-Works), S. Tagg, J.P., M.Inst.C.E., and John Terrace, M.Inst.C.E. Representatives of the University of Leeds: Prof. J. W. Cobb, C.B.E., B.Sc., F.I.C. (Honorary Secretary); Emeritus Prof. J. B. Cohen, Ph.D., D.Sc., F.R.S.; Emeritus Prof. Arthur Smithells, C.M.G., D.Sc., F.R.S.; and G. R. Thompson, B.Sc. Research Chemists: James W. Wood, M.Sc. (Tech.), A.I.C., and F. J. Dent, Ph.D. Research Assistants: W. H. Blackburn, Ph.D., A. R. Kelly, B.Sc., N. H. Williams, M.Sc., E. Parrish, B.Sc., and W. J. G. Davey, B.Sc.

There has been one change in the membership of this Committee since the last Report, due to the resignation of Mr. Thomas Glover, whose aid has been greatly appreciated. His place has been taken by Mr. John Terrace. The Committee has continued its work under the Chairmanship of Mr. Thomas Hardie, but arising from the feeling that the research work should be pressed forward and augmented in amount, two additional research assistants have been appointed, Mr. E. Parrish and Mr. N. H. Williams. Moreover, the resignation of Mr. G. B. Howarth on his appointment as Chief Chemist to the Newcastle and Gateshead Gas Company, which brought to a close a long term of useful service to this Committee, led to the appointment of Mr. G. N. Critchley, succeeded after a brief period by Mr. W. J. G. Davey. These changes in staff have inevitably had their effect upon the continuity of the research work carried out during the year, since in the case of each new appointment, there is something of a special technique to be mastered, which adds to the labour and responsibilities of the existing staff, particularly the Chief Chemists, Mr. Wood and Dr. Dent. They are to be congratulated upon the work they have been able to carry out, and the results they have been able to obtain, which are reported below.

25TH REPORT.

Mr. Wood has continued his systematic examination of products of combustion from typical gas appliances, with special attention to the production of CO. A surface combustion water-heater was tested, and it was again demonstrated how very small is the amount of CO generated with this type of burner, while incidentally the thermal efficiency of the appliance was determined.

The inverted incandescent lighting burner, with and without globes, was also subjected to examination under very varied conditions of use, and although a considerable rise in CO was found to occur in some experiments, this was on very low gas consumption, which ought not to occur in practice, the results under any reasonable conditions of operation being satisfactory. It would, however, point to the advisability of using small burners and mantles for low gas consumptions, rather than the turning down of the gas supply to a burner and mantle of larger size.

Another burner examined was that of the Fairweather Recording Calorimeter, because of the necessity felt of ensuring that the combustion in determining the calorific power of gas in the instrument was such that no error would arise from the presence of products of incomplete combustion. This was found to be the case.

Critical attention has also been paid to methods which have been put forward recently for a more rapid determination of CO than the one adopted for the purpose of our reports. A considerable speeding up seems to be possible if a high order of accuracy is not required.

Mr. Wood reported to the Committee on a visit paid to the Gas and Water Exhibition in Berlin in 1929, and it was thought that some of his observations were such as might with advantage be reported to the Institution, including those on a simple method of demonstrating the behaviour of flames by patterns scorched on wood.

All the matters so far mentioned are embodied in the 25th Report. The experimental work has been carried out in the laboratories of the Meadow Lane Gas-Works, and the Committee would like to express its thanks to the Leeds Corporation Gas Department and Mr. C. S. Shapley for the continuation of facilities there afforded.

With the approval of the Committee, Mr. J. W. Wood and Mr. G. B. Howarth accepted an invitation to present to the Second World Power Conference, 1930, held in Berlin, a paper entitled "Principles of design, construction, and operation of domestic gas heating equipment."

26TH REPORT.

During the year, a series of laboratory experiments has been made on the cracking of gas-oil, creosote, and mixtures in various atmospheres, with a view to throwing light upon the possibility of utilizing creosote in a carburetted water gas plant or in some similar way. This work is not completed, but in view of the importance of the subject, the present position of the investigation has been dealt with in the 26th Report. The results are not promising as regards utilization of creosote in this manner, but laboratory experiments are now being carried out at higher temperatures under somewhat different conditions.

27TH REPORT.

The Committee has desired for some time past to resume its examination of gas-making processes on the full working scale, and a suitable opportunity presented itself through the courtesy of the Gas Light and Coke Company, who placed at its disposal a Humphreys & Glasgow carburetted water gas plant working with a "back-run" of steam through the carburettor and generator. This plant was at the Stratford Works, and in its examination the Committtee would like to recognize the assistance rendered by Mr. Hutchence, the Station Engineer, Mr. Rogers and Mr. Culbertson and other members of his staff. Results, which have only been obtained in time for the Autumnal Research Meeting by strenuous exertions on the part of Dr. Dent and his staff, are set out in the 27th Report. It is hoped to be able to amplify them in the next report after carrying out tests on another plant at Nine Elms, which it will be possible to work for comparative purposes in the two ways, with and without the back-run.

No attempt has been made in this Report, which is essentially of a preliminary character, to describe in any detail the special devices which it has been found advisable or necessary to use, in order to carry out this test satisfactorily. Moreover, when the process of carburetted water gas making, already complicated, is further complicated by the addition of the back-run, it is plain that the calculations involved are of a correspondingly complicated kind, and in some cases may be not easy to follow. They have, however, been made with great care, and the collected Tables in the Report summarize the results of a much more

complete thermal and chemical examination of the process than has ever been carried through before.

SECOND REPORT ON THE USE OF CREOSOTE IN THE MANUFACTURE OF CARBURETTED WATER GAS.

In the 24th Report of the Joint Research Committee the possibilities of using creosote in the manufacture of carburetted water gas were discussed, and a programme of research was proposed, the results of which would enable the thermal yield of gas obtainable from the creosote to be estimated.

The experience of previous investigators indicated that difficulties arose on the plant, caused by deposition of naphthalene, when creosote alone was sprayed into the carburettor, and the most promising method of using it appeared to be as a mixture of creosote with a larger volume of petroleum gas oil. Under the varying conditions of a large scale plant, accompanied by the difficulty of accurate measurement, reliable data on the performance of creosote were not obtainable when it was used in such mixtures. Consequently, it was proposed in the 24th Report to carry out experiments under the controlled conditions of the laboratory. These experiments are now completed.

Gas oil, light and heavy creosote, and mixtures of gas oil and creosote have been cracked over the temperature range of 700° to 900° C., in atmospheres of (*a*) hydrogen, (*b*) hydrogen and carbon monoxide, and (*c*) hydrogen, carbon monoxide, and steam. The last atmosphere had a composition approximating to that of the gases in the carburettor of large scale practice. The figures in the following table are typical results, and were obtained by cracking at 800° C., in an atmosphere of hydrogen and carbon monoxide.

TABLE A.

Nature of Oil.	Therms as Oil Gas per Gallon of Oil.	Tar per Cent. by Weight of Oil.	Naphthalene in Tar per Cent by Weight of Oil.
Gas oil	1·211	30·1	3·0
Light creosote (from steamed vertical retorts)	0·489	67·7	16·0
Heavy creosote (from horizontal retorts)	0·167	80·3	18·3
Mixture of 80 per cent. gas oil and 20 per cent. light creosote by volume	1·054	40·1	6·3

These results illustrate the low thermal yields of gas given by creosote, when cracked under conditions similar to those prevailing in the carburettor and superheater of a carburetted water gas plant. The amount of tar obtained was correspondingly high, and it is to be noted that the tar from creosote contained five to six times as much naphthalene as did the tar obtained when gas oil was used.

The table includes also the yields of gas, tar, and naphthalene, obtained from a mixture consisting of 80 per cent. gas oil and 20 per cent. creosote, by volume. By subtracting from these figures the corresponding yields given by the amount of gas oil contained in the mixture when used alone, figures are obtained which represent the net performance of the creosote in such a mixture. The following results have been obtained in this manner :—

Yields of Products Obtained from Light Creosote when Used in a Mixture Consisting of One Volume of Creosote and Four Volumes of Gas Oil

Therms of Oil Gas per Gallon.	Tar per Cent. by Weight.	Naphthalene in Tar per Cent. by Weight.
0·425	75·0	18·0

These results are slightly worse, from the gas-making point of view, than those obtained when the creosote was used alone. Consequently the conclusion is reached that, although dilution of the creosote with gas oil may avoid mechanical troubles on the plant, the presence of the gas oil does not increase the thermal yield of gas given by the creosote, above the low value obtained when using the creosote alone.

The investigation of the cracking of creosote is being continued, under conditions of temperature and atmosphere not imposed by those normally existing in the carburettor and superheater of a carburetted water gas plant. The highest thermal yield of gas obtained so far in these experiments is 0·83 therm. This figure is the result of an experiment in which light creosote was cracked in an atmosphere of hydrogen at 1100° C. Under such conditions, no liquid tar was obtained and the amount of naphthalene produced was relatively small. A considerable quantity of sooty matter was formed, however, and was deposited in the cool gas exit from the furnace. Further experiments will be carried out at lower temperatures with particular regard to the yield of light oils obtained.

Prof. J. W. COBB, in a brief introduction to the Report, said : This particular report is a very short one, dealing with the possibility of the use of creosote in water gas plants. As a matter of fact, the material available in our hands for the preparation of a report on the subject is very much greater than is dealt with here, but it is proposed to deal with it further in a later report. Dr. Dent and his assistants had to work so strenuously in order to get through the tests necessary in connection with the report which is to be presented later on the back-run water gas process that they have not had time to work up the whole of the material on creosote in a form suitable for presentation in a report. At the same time, we knew that this was an urgent and an interesting matter, and one in regard to which the National Gas Council as well as the Institution were waiting for some sort of information and report. Therefore, the report now presented is a summarized statement of our results rather than a detailed account of the investigations leading up to them.

Dr. DENT then presented the report.

DISCUSSION.

The PRESIDENT : This subject of the cracking of creosote is rather an involved one, particularly on the question of temperature. It is the problem of temperature that requires very careful investigation. I have tried various temperatures and I have practically come to the conclusion that it canot be done straightforwardly. I suggest that the easiest way to do it is to raise the temperature of your vessel—the carburettor or whatever you are going to use creosote in—to a point which is ideal for the cracking of creosotes, and then work backwards. I am not sure, but I suggest that this is the direction in which a solution will be found.

RESULTS FROM LIGHT AND HEAVY CREOSOTES.

Mr. R. H. GRIFFITH : There is one matter referred to in this report which appeals particularly to a chemist, and that is the large difference between the results obtained with light and with heavy creosotes. In both cases the yields of gas are considerably lower than might have been expected. In the case of petroleum oils, if the therm yield is plotted against the content of open-chain hydrocarbons present, the resulting straight line cuts the therm axis at a value of about 0·6 therm. That means that cyclic hydrocarbons which are present are capable of giving rise to a certain amount of gas. In a light creosote the open-chain hydrocarbon content is something of the order of 30 p.ct., but with a heavy creosote it is considerably smaller. Accordingly, one might expect a yield of something of the order of 0·8 therm per gallon from a light creosote and at least 0·6 therm from a heavy creosote. But there is another factor, and one of greater importance, involved in this question. It is that the whole of the oil composition is not revealed by the simple group analysis. Although the group analysis shows the difference between naphthalenic and aromatic cyclic hydrocarbons, it does not show the presence or absence of side chains on the aromatic nucleus. In the petroleum hydrocarbons there are generally side chains of varying length which can yield methane or ethane or other rich gas by their decomposition. The difference between petroleum hydrocarbons and those obtained by high-temperature carbonization of coal is that in the former there are these side chains, but they are not present in the latter. Prof. Morgan has shown the same sort of thing as the result of his researches on low-temperature tar. In that tar these side chains are still present. The presence of substituted naphthalene in low-temperature tar, but the almost complete absence of naphthalene itself, is a good illustration of that case. The creosote fractions separated from low-temperature tar gives considerably more gas than the corresponding fraction from a high-temperature tar. That falls into exactly the same line. Owing to the drastic treatment which the high-temperature carbonization has given to these hydrocarbons there is very little hope of any further change occurring in that way, and I think that the results which Dr. Dent has reported are about the maximum that can be hoped for from this material.

NEW CARBURETTING TECHNIQUE.

Dr. G. W. ANDERSON : There are two matters of interest in this report to which I should like to call special attention.

Stress has been laid on the fact that a considerable amount of naphthalene is produced and is contained in the tar when creosote is used instead of gas oil. In this connection I should like to ask Dr. Dent to say whether the original creosote oil did contain naphthalene. If so, one would not be surprised. On the other hand, of course, naphthalene would obviously be the result of the cracking of creosote oil in any case. With regard to the thermal efficiency obtained with creosote oil, it is a little surprising to find that there is any cracking taking place at temperatures between 700° and 900° C., because that creosote oil must have been subjected to considerable temperatures before it was obtained from tar distillation, particularly when it comes from horizontal retorts. It seems to me that the most important part in this report is contained in the last paragraph, in which it is said that at a higher temperature—1100° C.—and in an atmosphere of hydrogen, practically all gas and some carbon is produced. Having regard to the nature of the creosote and its origin, it seems that perhaps a new technique of carburation must be developed if creosote oil is to be used as a carburant. I am thinking of the injection of creosote into the generator itself, and in this connection I should like to draw attention to some work which has been done at the Frankfurt Gas Company's Works. That Company has developed within the last 12 or 18 months a process which is now in operation at Frankfurt. In this process ordinary coal tar or lignite tar is injected into the fuel bed of the water gas generator. It is not a new process; it has been tried before, but it appears that this Company has overcome the technical difficulties which usually accompany the cracking of tar in the generator bed. It seems to me that the Company's success might show the way to the use of creosote oil in a similar manner. When lignite tar was used, 12 p.ct. of it was obtained again as tar, while the rest appeared as gas. The mixture of the blue water gas and the gas produced from the cracking of the lignite tar resembled very closely the town gas ordinarily produced from the carbonization of coal and the addition of water gas. It has a specific gravity of about 0·54 and the following composition:

Carbon dioxide	3·2 p.ct.
Heavy hydrocarbons	4·7 ,,
Oxygen	0·5 ,,
Carbon monoxide	34·4 ,,
Hydrogen	46·2 ,,
Methane	8·8 ,,
Nitrogen	2·2 ,,

The main claim here is that this gas can be used in ordinary burners, and that the plant used would be very usefully employed as peak load plant without producing any effect on consumers' appliances. The cold-gas efficiency of the process is given as about 50 p.ct. Complete details are available with regard to the cost of operation and cost of plant. In regard to the latter point, it seems to me that we can do away with the superheater and the carburettor, in which case we should reduce materially the cost of plant, which is said to be about 20 or 25 p.ct. higher than that of ordinary blue water gas plant.

Mr. THOMAS HARDIE (Past-President): The Report has shown very clearly, I think, that, so far as the use of creosote in carburetted water gas plant in the ordinary way is concerned, we cannot look in that direction for much hope of getting rid of our surplus creosote. Dr. Anderson has mentioned that the Frankfurt Gas Company has adopted the method of injecting tar into the generator. This system, or a system similar to the one in use at Frankfurt, has been common practice for some years in the States, where they are using with very great success bunker oil—a heavy oil—and it has certainly occurred to me that more satisfactory results might be obtained if creosote were used in that system. In this country already a generator has been constructed, embodying the necessary modifications to enable this to be done; and I hope that very shortly it will be possible to give some particulars of the use of creosote in that particular way.

The PRESIDENT: I should be glad if Dr. Dent could give us some indication as to the approximate temperature at which light creosote is most successfully cracked, in an atmosphere preferably of water gas, or, failing that, an atmosphere of hydrogen.

Dr. DENT: We have increased the temperature for cracking creosote in hydrogen up to 1300° C. The maximum yield of gas obtained, however, as shown in the report, was 0·83 therm, and this was obtained at 1100° C.

I should like to thank the speakers for their very interesting remarks, which add considerably to the value of the report. The only remaining question I have to deal with is that raised by Dr. Anderson concerning how much naphthalene was present originally in the creosote. I have no actual figures with me at the moment, but I can say that most of the naphthalene shown here as being present in the tar has been formed during the cracking.

27th Report of the Joint Research Committee of the Institution and Leeds University

1st Report on the Back-Run Process for the Manufacture of Carburetted Water Gas

Research Chemist: F. J. Dent, Ph.D. *Research Assistants:* W. H. Blackburn, Ph.D., N. H. Williams, M.Sc., and E. Parrish, M.Sc.

[Abstract.]

The test was carried out on a carburetted water gas set at the Stratford Works of the Gas Light and Coke Company. The plant was erected by Humphreys & Glasgow, Ltd., and was first put to work in November, 1928.

The test was of 96 hours' duration, and the results obtained, including carbon and heat balances, are given in the Tables at the end of the Report.

It is not thought advisable at this stage of the investigation to compare too closely the results obtained with those given in the 7th Report. Apart from the difficulty of completely separating the individual influences of back-run steaming, self-clinkering grate, and the shorter cycle used, comparison is made more difficult by differences in the coke and in the amount and nature of the oil used. It is proposed to continue the investigation on a plant which can be operated with or without back-run steaming, when it is hoped that results will be obtained which will render direct comparison less difficult. In the following account of the results obtained in the test at Stratford, only major variations from those given in the 7th Report will be indicated.

Coke.—The coke used in the test was obtained by carbonizing Durham coal in horizontal retorts, and was passed over screens of 2-in. mesh before being transported to the plant. It was then forked into trucks, and, after weighing, elevated to the coke hoppers from which the charging skips were filled. The coke contained 4·1 per cent. of moisture and the dry coke 8·9 per cent. of ash. The complete analysis of the coke is given in Table VII.

Oil.—The oil was an American petroleum distillate, the amount used being equivalent to 2·11 gallons per 1000 c.ft. of carburetted water gas. With this amount of oil the calorific value of the carburetted water gas averaged 503 B.Th.U. per cubic foot.

i. The Generator, and the Efficiency of Blue Water Gas Production.

Coke to Generator.—The weight of dry coke supplied to the generator was 34·08 lbs. (equivalent to 29·88 lbs. of carbon) per 1000 c.ft. of carburetted water gas made. In the generator, the heat of this coke is utilized for the production of blue water gas and for raising steam in the annular boiler. The amount of steam raised in the boiler was 26·9 lbs. per 1000 c.ft. of carburetted water gas at a pressure of 30·5 lbs. per sq. in. If this steam had been raised in an independent boiler of 70 per cent. efficiency 3·13 lbs. of coke would have been required. Consequently, if an allowance is made for the steam raised, the amount

of coke supplied to the generator is reduced from 34·08 lbs. to 30·95 lbs. per 1000 c.ft. of carburetted water gas. In comparing this result with those of other tests of generators it must be remembered that this figure was obtained when part of the steam supplied was superheated in the carburettor and superheater.

In Table IX. a balance is set out between the carbon entering and leaving the generator. Carbon enters the generator mainly as coke, but a small amount as carbon monoxide, carbon dioxide, and methane accompanies the back-run steam as it leaves the top of the carburettor. The carbon leaving the generator is distributed among (1) blue water gas, (2) ashes and clinker, (3) fliers, and (4) blow gas and carbon unaccounted for. The fourth item, which has been obtained by difference, consists mainly of carbon leaving the generator as blow gas, but it also includes the solid carbon which is carried forward during the run period, and that portion of the solid carbon suspended in the blow gas which is not recovered as "fliers."

The amount of carbon in the ashes and clinker was 2·61 per cent. of the total carbon supplied to the generator. The average of the corresponding figures in the three tests described in the 7th Report was 7·15. The difference, which is equivalent to approximately 1·5 lbs. of coke per 1000 c.ft. of carburetted water gas, demonstrates a direct economy of fuel effected by the self-clinkering grate.

Steam to Generators.—The quantities and rates of steam supplied and the percentage of the steam decomposed during the different phases of the cycle are given in Table V. It is seen that a much higher rate of steam supply was used during the back-run than during the up-run, in spite of the lower temperature of the fuel bed during the former period. The high rate of back-run steaming was employed to prevent the formation of clinker in the upper zones of the fuel bed, where it cannot be broken and extracted by the grate. The arrangement, however, is defective from the point of view of steam economy and leads to a low percentage of steam decomposed during the back-run.

The total quantity of steam supplied to the set was 32·83 lbs. per 1000 c.ft. of carburetted water gas made. Of this amount, 15·94 lbs. passed through the fuel bed during the up-run, 12·23 lbs. during the back-run, and 1·14 lbs. during the purge. As mentioned previously, at the end of the back-run, the carburettor and superheater were left full of steam, which was swept forward to the wash box during the purge. The quantity of steam lost in this way was calculated from the temperature and internal volumes of the carburettor, superheater, and free space in the generator above the fuel bed, and was found to be 2·64 lbs. per 1000 c.ft. of carburetted water gas made. This amount of steam is equivalent to 8·0 per cent. of the total steam supplied. The remaining item "steam unaccounted for" was obtained by difference, and consists of leaks and errors, less any steam arising from the water seals.

During the back-run, the steam, after passing through the superheater and carburettor, entered the generator, together with gases formed by the gasification of carbon, &c., in the cracking chambers, at a temperature of 650° C. The amount of heat carried back to the generator in this way equals the sum of items 10, 11, and 12 in Table XIV., in which a heat balance of the carburettor, superheater, and waste heat boiler is set out. The sum of these three items is 0·078 therm per 1000 c.ft. of carburetted water gas made, and is equivalent to 5·06 per cent. of the heat present in the blow gases leaving the generator. This recuperation of heat to the generator, which is a feature of the back-run process, was accompanied, however, by a loss of the total heat of the 2·64 lbs. of steam which was swept out of the carburettor and superheater at the end of the back-run at a temperature of 600° C. This loss of heat is equivalent to 0·043 therm per 1000 c.ft. of carburetted water gas. It follows that the net amount of heat recuperated equals the difference of these two figures—namely, 0·035 therm. This amount of heat, which as an item in a heat balance of the complete process of the production of carburetted water gas would only equal 0·4 per cent., cannot be regarded, however, as a direct heat recovery since the introduction of back-run steaming is accompanied by a reduction in the performance of the waste heat boiler. Consequently, the conclusion is reached that back-run steaming, regarded merely as a means of recuperating heat from the blow gases, does not appreciably increase the thermal efficiency of the production of carburetted water gas.

The heat absorbed by the back-run steam from the carburettor and superheater can, however, influence the efficiency of the generator, as the following considerations show.

When steam combines with carbon to give water gas the chemical reactions taking place can be regarded as being a combination of two reactions, viz. :—

(1) C (12 lbs.) + H_2O (18 lbs. vapour at 100° C.) ⟶ $CO + H_2$ − 50,700 B.Th.U.

and

(2) C (12 lbs.) + $2H_2O$ (36 lbs. vapour at 100° C.) ⟶ $CO_2 + 2H_2$ − 31,200 B.Th.U.

The heat quantities 50,700 and 31,200 B.Th.U. are the amounts of heat absorbed in the reactions per 12 lbs. of carbon gasified when the carbon is initially at 15·5° C., the steam at 100° C., and the final products, carbon monoxide, carbon dioxide, and hydrogen, are cooled to 15·5° C. These heat quantities do not represent the heat absorbed from the fuel bed in the generator of a water gas plant, where the initial temperature of the carbon and the final temperatures of the gases produced are much higher.

Assuming that the temperature of the fuel bed is 1000° C., that the steam enters at 100° C., and that the gases leave the zone of reaction at 900° C., these equations become modified to :—

(1a) C (12 lbs. at 1000° C.) + H_2O (18 lbs. vapour at 100° C.) ⟶ CO (900° C.) + H_2 (900° C.) − 63,200 B.Th.U.

and

(2a) C (12 lbs. at 1000° C.) + $2H_2O$ (36 lbs. vapour at 100° C.) ⟶ CO_2 (900° C.) + $2H_2$ (900° C.) − 57,900 B.Th.U.

It follows from these two equations that when steam reacts with carbon in the fuel bed, producing water gas with the composition of the back-run gas (see Table II.), 0·0319 therm are absorbed per lb. of steam decomposed.

During the back-run, the amount of steam supplied to the fuel bed per 1000 c.ft. of carburetted water gas was 12·23 lbs., 48·4 per cent. of which was decomposed. Using the figure obtained above, it can be shown that this process involved an absorption of heat equivalent to 0·244 therm per 1000 c.ft. of carburetted water gas. This figure is based on the assumption that the steam enters the generator at 100° C. If superheated steam is used, however, the heat absorbed from the fuel bed will be decreased by an amount equivalent to the superheat of the steam. In the test described in this Report, the superheat of the back-run steam entering the generator was 0·061 therm per 1000 c.ft. of carburetted water gas (item 10, Table XIV.). Consequently, the heat absorbed in the fuel bed, using such superheated steam, equals 0·244 *minus* 0·061 = 0·183 therm. This reduction in the quantity of heat absorbed is considerable, and is sufficient to allow of an appreciable increase, either in the rate of steaming or in the relative duration of the steaming period, or both; any one of these alternatives would lead to a reduction in the proportion of heat lost in the blow gases. It is believed that it is in this way that the greatest increase in the thermal efficiency of the production of carburetted water gas, consequent on the introduction of the back-run, will be obtained.

The Thermal Efficiency of Blue Water Gas Production.—In Table XIII. a heat balance of the generator is set out. The heat supplied to the generator consists of five items. The second item gives the total heat of the steam which entered the generator. The heat of the steam left in the carburettor and superheater at the end of the back-run is not included, since it is intended that this heat balance should represent the performance of a generator alone, supplied during the down-run with superheated steam, regardless of the method employed to superheat the steam.

The heat leaving the generator is distributed among the

twelve items given in Table XIII. It is noteworthy, in view of the conclusions as to the influence of the use of superheated steam, that the ratio of the potential heat of the blue water gas to the total heat of the blow gas is greater than in any of the tests described in the 7th Report. This is in spite of the fact that the presence of the generator boiler rendered it necessary to generate more heat during the blow period than would otherwise have been necessary.

TABLE A.—*Heat Quantities as Per Cent. of the Total Heat Entering the Generator.*

—	7th Report.			Present Report.
	Test No. 1.	No 2.	No. 3.	
Blue water gas, potential heat $= x$	49·85	49·45	50·17	51·27
Blow gas, potential and sensible heat $= y$	32·39	33·18	32·63	31·88
Ratio $= \frac{x}{y}$	1·54	1·49	1·54	1·61

In Table I. the efficiency of blue water gas production is expressed in two ways, depending on whether or not the steam required in excess of that raised by the generator boiler is taken into account. These efficiencies have been calculated according to the principle defined in the Clark-Smithells-Cobb report to the Institution in 1919—*i.e.*, the thermal efficiency is given by the heat in the gas multiplied by 100 and divided by the sum of the heat in the gas and the heat used and lost in manufacture. As no credit is allowed for the potential heat in the fliers and ashes, it follows that the sum of the heat in the gas and the heat used and lost in manufacture is equal to the amount of heat supplied to the generator, *plus* the heat used in raising the excess steam required for generator and auxiliary plant, and is the sum of the following items :—

—	Therms per 1000 C.Ft. C.W.G
(*a*) Coke to generator	4·399
(*b*) Sensible heat of air to generator	0·004
(*c*) Heat required to raise the steam for generator in excess of that raised in the annular boiler (boiler efficiency 70 per cent.)	0·055
(*d*) Heat required to raise the steam for the auxiliary plant (boiler efficiency 70 per cent.)	0·462
(*e*) Heat as superheat in back-run steam	0·061
Total	4 981

The potential heat of the blue gas produced in the generator equals the potential heat of the total blue gas, less that of the gas produced by reaction between the back-run steam and the carbon, dense hydrocarbons, &c., on the chequer work of the carburettor and superheater. This equals 2·471 − 0·016 = 2·455 therms per 1000 c.ft. of carburetted water gas.

Consequently, the efficiency of blue water gas production

$$= \frac{2\cdot455 \times 100}{4\cdot981} = 49\cdot3 \text{ per cent.}$$

If the heat required to raise the steam used in excess of the amount raised by the generator boiler is not taken into account, this becomes

$$\frac{2\cdot455 \times 100}{4\ 981 - [\text{items } (c) \text{ and } (d)]} = \frac{2\cdot455 \times 100}{4\cdot464} = 55\cdot0 \text{ per cent.}$$

ii. The Carburettor and Superheater and the Efficiency of Oil Cracking.

The oil used in the carburettor was equivalent in amount to 2·11 gallons per 1000 c.ft. of carburetted water gas and yielded 1·21 therms as oil gas per gallon of oil. An average of 1·29 therms of oil gas was obtained per gallon of oil in the tests described in the 7th Report, and the yield of tar was correspondingly lower, viz., 15·0 gallons per 100 gallons of oil, as against the 22·0 gallons recovered in the present test.

It is inadvisable to conclude from these figures that cracking conditions on the "back-run" plant are not as favourable to a high thermal yield of oil gas as on a plant operated without back-run steaming, since the difference observed may be due to a variation in the quality of the oil used. It should be noted, however, that back-run steaming necessitates an increase in the rate of oil admission, and in this way introduces a factor which will tend to decrease the cracking efficiency of the oil. General experience has shown that the thermal yield of oil gas decreases with an increase in the rate of oil supply. This conclusion has been confirmed by laboratory experiments,* the results of which indicated that the presence of the hydrogen of the blue gas considerably influences the yield of oil gas obtained. It was shown that, within limits, the higher the ratio of the concentrations of hydrogen to the concentration of oil vapour in the gases, the higher is the thermal yield of oil gas.

Since, when using a cycle including back-run steaming, oil is only injected when the fuel bed is steamed in an upward direction, it follows that, when making carburetted gas of a given calorific value, the rate of oil supply to the carburettor of a back-run plant will be considerably higher than in a plant operated without back-run steaming. For example, in the present test the rate of oil supply was 5·63 gallons per 1000 c.ft. of blue water gas produced during the period of oil admission, whereas the corresponding figure using a cycle similar to the one described in the 7th Report, in which the oil was injected during 3 minutes of a 4-minute gas-making period, is only 3·38 Such a difference in the rate of oil supply is sufficient to influence appreciably the cracking efficiency, but from the single test in this report we cannot conclude how far any disadvantage of the back-run in this respect is negatived by an accompanying improvement in the temperature distribution in the carburettor and superheater.

The temperatures in the carburettor and superheater during the various phases of the cycle are given in Table IV. The temperatures of these chambers as a whole are higher than in the tests described in the 7th Report, but the influence of the back-run steam in maintaining a lower temperature at the top of the superheater is to be noted. The lower temperature at the top of the superheater tends to reduce the heat lost as sensible heat in the run gases leaving the set. The back-run cycle leads to a further reduction, since the blue gas produced during the down-run leaves the base of the generator at a relatively low temperature (350° C. in the present test), and passes directly to the wash box without reheating in the carburettor and superheater. The amount of carbon gasified in the carburettor and superheater by the back-run steam was determined by taking samples of the steam in evacuated bottles. The amounts of steam and accompanying gas were then determined, and an analysis of the gas made. Samples were taken during the back-run (*a*) at the top of the superheater and (*b*) at the top of the carburettor. The amount of carbon, present as carbon dioxide and monoxide, in the samples taken at the top of the carburettor, in excess of that present in the samples taken at the top of the superheater, was taken to be the amount gasified by the steam.

At the commencement of the back-run the carburettor and superheater were filled with blue gas remaining from the up-run period, and any inclusion of this gas in the samples would have led to a high figure for the carbon gasified by the steam. In order to minimize errors due to this cause, as long a time as possible was allowed for the sweeping out of the up-run blue gas by the steam, and the samples were taken towards the end of the back-run. This procedure had the disadvantage that at the end of the back-run the temperature of the carburettor and superheater had been somewhat reduced by the passage of the steam, and, consequently, the rate of gasification at that time would be lower than the average rate. The results obtained would also be low if, during carburetting, some of the carbon and hydrocarbons were deposited in a "sooty" form and if this material were rapidly gasified at the beginning of the back-run. It is not thought, however, that errors so introduced would be sufficiently large to influence the conclusion, drawn from Table X., that the amount of carbon gasified by steam in the carburettor and superheater during the back-run was small under the conditions of cycle and nature of oil prevailing during the test. This conclusion has been confirmed by cracking gas oil in an atmosphere of steam at 800° C. in a laboratory

* R. H. Griffith, J.S.C.I., 252T, 48, 1929.

apparatus; the amount of carbon monoxide and dioxide, produced by interaction of the steam with hydrocarbons and carbon deposited during the cracking, was small.

Steam Raised in the Generator and Waste Heat Boilers.—Table XI. gives the amounts of steam raised in the generator and waste heat boilers. It was observed that the quantity of water evaporated in the generator boiler depended to some extent on the conditions in the fuel bed. The presence of clinker or small coke over the top of the grate, by impeding the passage of the blast through the centre of the fire, led to a higher temperature round the sides of the bed, thus increasing the amount of heat absorbed by the boiler with a corresponding decrease in the amount remaining for blue gas production. Throughout the test, using a horizontal Durham coke, the fire was clear and consequently the amount of steam raised in the generator boiler, 26·9 lbs. per 1000 c.ft. of gas made, approached its minimum value. This amount of steam was less than that supplied to the generator by 5·9 lbs.

The heat balance of the waste heat boiler is set out in Table XV., where it is seen that the heat in the 35·6 lbs. of steam raised in the boiler was only 30·9 per cent. of the total heat entering the boiler. It is thought that the performance of this boiler could have been improved by admitting air to the top of the superheater in order to liberate some of the potential heat in the waste gases. The results of surveys of the composition of the waste gases, made over individual " blow " periods, indicated that air could with advantage have been admitted during the latter half of the blow.

The adoption of such a procedure would not, however, have increased the steam output to that of the waste heat boiler in the installation tested at Birmingham and described in the 7th Report, since the total heat entering the boiler, *i.e.*, the potential and sensible heats of the waste gases, was considerably less in the present test.

TABLE B.—*Heat Quantities expressed in Therms per 1000 C.Ft. of C.W.G.*

—	7th Report.			Present Test.
	Test No. 1.	No. 2.	No. 3.	
Heat entering boiler as waste gas	1·599	1·562	1·564	1·202
Total heat of steam raised	0·670	0·774	0·679	0·371
Thermal efficiency of boiler, per cent.	41·9	49·6	43·4	30·9

The following are factors which tend to reduce the amount of steam raised in the waste heat boiler when the plant is operated on a cycle including back-run steaming :—

(*a*) Heat is absorbed from the carburettor and superheater during the back-run and appears as superheat in the steam, and potential and sensible heat in the accompanying gases. Part of this heat is returned to the generator and part is swept forward to the wash box.

(*b*) Owing to the smaller amount of heat leaving the generator as blow gas, less heat is available in the waste gases.

(*c*) The higher temperature maintained in the carburettor and superheater requires a greater proportion of the heat of the blow gases to be developed before they reach the waste heat boiler.

In the test described the influence of these factors was not counterbalanced by the reduction in the loss of sensible heat in the carburetted and blue gases and in the tar vapours leaving the set.

iii. The Thermal Efficiency of Carburetted Water Gas Production.

The thermal efficiency of the production of carburetted water gas on this test is given in Table I. as 69·3 per cent. This figure, which takes into account the heat necessary to raise the total steam required in excess of that raised in the generator and waste heat boilers, has been obtained using a method similar to that employed in the calculation of the corresponding efficiency of blue water gas production. Thus the thermal efficiency of the production of carburetted water gas equals the potential heat of the carburetted gas divided by :—the sum of the heat supplied as coke, oil, and air, and the heat required to raise the extra steam, less the potential heat of the tar produced.

The Volume of Gas Produced per Day.—It is difficult to ascertain from the results in the 7th Report and those of the present test exactly to what extent the introduction of back-run steaming is responsible for the considerable increase in the volume of gas produced per day from generators of similar size, owing to differences in the construction, cycles of operation, and fuel. The full consideration of the influence of the back-run on this important aspect of the manufacture of carburetted water gas must be postponed until results have been obtained for both methods of working on the same generator and using the same coke. The following table is, however, given as a matter of interest and as representing actual performances :—

TABLE C.

—	Present Test.	7th Report Tests—Average.
Nature of coke	Horizontal coke from Durham coal	Vertical coke from coal from various sources
Gallons of oil per 1000 c.ft. C.W.G.	2·11	1·83
Internal diameter of generator	7 ft. 7 in.	..
Diameter of grate	..	8 ft.
Average rate of steam supply to fuel bed during "run" periods in lbs. per minute	100·6	50·8
Steam to fuel bed decomposed per cent.	68	70
Average rate of air supply to generator during "blow" periods in c.ft. per min.	7,400	6,220
Average rate of production of blue water gas during "run" periods	2,660	1,450
Average rate of production of blow gas during blow periods	8,200	6,910
Ratio of time of "run" to time of "blow"	1·29	2·0
Volume of C.W.G. made in c.ft. per day	2,384,000	1,479,000
Thermal value of C.W.G. made per day in therms	11,990	7,150
Volume of B.W.G. made in c.ft. per day	2,024,000	1,242,000
Thermal value of B.W.G. made per day in therms	5,890	3,630

VALUES EMPLOYED IN PREPARING TABLES.

The values given below have been employed in the calculations made in the preparation of the tables in this report.

Heat Capacities in B.Th.U. per Cubic Foot (60° Fahr., 15·5° C., and 30 in. moist). Heat Capacity of Water Vapour in Gas not included.

t = temp. ° C. *minus* 15·5.

H_2 and N_2	$0{\cdot}032t + 0{\cdot}00000187t^2$
O_2 and CO	$0{\cdot}0322t + 0{\cdot}00000234t^2$
CO_2	$0{\cdot}0418t + 0{\cdot}00001171t^2$
H_2S	$0{\cdot}0381t + 0{\cdot}00000468t^2$
CH_4	$0{\cdot}043t + 0{\cdot}0000453t^2$
C_mH_n	$0{\cdot}0723t + 0{\cdot}0000889t^2$

Heat Capacities in B.Th.U per lb.

t_{100} = temp. ° C. *minus* 100.
t = temp. ° C. *minus* 15·5.

H_2O (vapour)	$0{\cdot}915t_{100} + 0{\cdot}000215t^2_{100} + 1116$
Ashes	$0{\cdot}36t$
Tar (vapour)	$0{\cdot}80t + 180$

Calorific Values of Gases in B.Th.U. per Cubic Foot (60° Fahr. and 30 in. Moist).

Gas.	CO.	H_2.	CH_4.
Calorific value, gross	318	320	992

TABLE I.—*General Results of Test.*

Duration of test in hours	96·00
Time of gasification in hours, including "blow" and "run" periods	90·25
Time for coking and inspection, in hours	5·75
Coke—	
Coke (wet) supplied to generator, in tons	151·30
Moisture in coke, per cent.	4·10
Coke (dry) supplied to generator, in tons	145·06
Coke (dry) to generator, in lbs. per 1000 c.ft. C.W.G.	34·08
Carbon supplied to generator as coke, in lbs. per 1000 c.ft. C.W.G.	29·88
Therms, as blue gas, per ton of coke	162·4
Oil—	
Oil supplied to carburettor, in gallons (corr. to 60° Fahr.)	20,163
Oil to carburettor, in gallons per ton of dry coke to generator	139·0
Oil to carburettor, in gallons per 1000 c.ft. C.W.G.	2·11
Therms in C.W.G. per gallon of oil	1·21

TABLE I. (*continued*).

Steam to set—	
Total steam supplied to generator, in lbs.	313,000
Steam to generator, in lbs. per ton of dry coke to generator	2,157
Steam to generator, in lbs. per 1000 c.ft. C.W.G.	32·83
Average percentage of steam decomposed	60·8
Carburetted water gas—	
Total C.W.G. (purified) made, in cubic feet (sat. 60° Fahr. and 30 in.)	9,534,000
C.W.G., in cubic feet per ton of dry coke to generator	65,720
C.W.G. made per day, in cubic feet	2,384,000
Calorific value of C.W.G., in B.Th.U. per cubic foot gross	503·0
Thermal value of C.W.G., in therms per ton of dry coke	330·3
C.W.G. made per day, in therms	11,990
Clinker and ashes—	
Total ashes and clinker (dry) withdrawn, in tons	14·73
Ashes and clinker (dry), in tons per ton of dry coke to generator	0·102
Carbon in ashes and clinker, as percentage of the carbon in coke supplied to generator	2·30
Fliers (dry) recovered, in tons per ton of dry coke to generator	0·0134
Tar (dry)—	
Total amount of dry tar recovered, in gallons	4,458
Dry tar recovered, in gallons per 100 gallons of oil	22·02
Dry tar recovered, in gallons per 1000 c.ft. C.W.G.	0·468
Boilers—	
(*a*) Generator boiler— Water evaporated at 30·5 lbs. per sq. in., in lbs. per 1000 c.ft. C.W.G.	26·9
Equivalent evaporation, in lbs. from and at 100° C.	29·2
(*b*) Waste heat boiler— Water evaporated at 98 lbs. per sq. in., in lbs. per 1000 c.ft. C.W.G.	35·6
Equivalent evaporation, in lbs. from and at 100° C.	38·2
Total equivalent evaporation in generator and waste heat boilers, in lbs. from and at 100° C.	67·4
Efficiency of the production of carburetted water gas,* per cent.	69·3
Efficiency of the production of blue water gas, per cent.*	
(*a*) Fuel required for the extra steam to generator and for the steam to auxiliary plant being taken into account (70 per cent. boiler efficiency)	49 3
(*b*) Fuel required for extra steam to generator and for the steam to auxiliary plant not being taken into account	55·0

* No allowance is made for the potential heat in the ashes, clinker, and fliers.

TABLE II.—*Analyses of Gases.*

CARBURETTED WATER GAS.

Average composition—volume per cent.

CO_2	4·1
C_mH_n	7·6
O_2	0·2
H_2	40·6
CO	35·2
CH_4	6·2
C_2H_6	1·6
N_2	4·6
Value of "m" in C_mH_n	2·94
Inerts, including oxygen	8·9
"True" inerts	7·9
Specific gravity of gas (air = 1)	0·65
H_2S in grains per 100 c.ft. at outlet exhauster	181
Calorific value in B.Th.U. per c.ft. (sat. 60° Fahr. and 30 in.)	503·0

Gas.	Blue Gas. Up-Run.	Back-Run.	Purge.	Blow Gas Accompanying Blue Gas.	Total Blue Gas.
Composition — vol. per cent.—					
CO_2	2·7	7·4	8·8	16·6	4·8
H_2	49·6	54·7	46·0	1·0	48·9
CO	45·7	36·6	42·1	7·3	41·4
CH_4	0·3	0·4	0·7	0·1	0·3
N_2	1·7	0·9	2·4	75·0	4 6
	100 0	100·0	100·0	100·0	100·0
Vol. per cent. of total blue gas	64·1	28·6	3·0	4·2	100·0
H_2S in grains per 100 c.ft.	141	448	..	..	218
Calorific value in B.Th.U. per c.ft. (calculated) gross	307·0	295·3	288·0	27·4	291·0

TABLR II. (*continued*).

Gas.	Blow Gas (Sampled Between Generator and Carburettor).	Waste Gas (Outlet Waste Heat Boiler).
Composition—vol. per cent.—		
CO_2	13 4	17·2
O_2	0·1	0·3
H_2	2·6	0 9
CO	12·2	5·2
CH_4	0·3	0·1
N_2	71·4	76·3
	100 0	100·0
Grains of sulphur as SO_3 per 100 c.ft.	36	58
Calorific value in B.Th.U. per c.ft. (calculated), gross	50·1	20·4

NOTE.—The calorific value given for the carburetted water gas is the result of determinations. The calorific values of the other gases have been calculated from their compositions and the data in the Appendix.

TABLE III.—*Pressures on Plant.*

	Blow.	Up-Run.	Back-Run.
Pressures in inches of water—			
Blast	20 0	22·0	22·0
Generator base	16·0	17·0	16·0
Generator top	8·0	16·5	18·0
Superheater top	3·5	16·0	19·0
Outlet condenser	..	10·8	..
Inlet exhauster		5·0	
Outlet exhauster		35·0	

TABLE IV.—*Temperatures on Plant.*

Temperatures in degrees centigrade—	
Up-run blue gas, generator to carburettor main	640
Carburetted gas, base of carburettor	780
,, ,, base of superheater	750
,, ,, top of superheater	710
,, ,, outlet wash box	83
,, ,, outlet condenser	24·4
,, ,, meter	19·0
Back-run steam, top of superheater	520
,, ,, base of superheater	750
,, ,, base of carburettor	770
,, ,, carburettor to generator main	650
Back-run blue water gas, outlet generator	350
Air, inlet blower	21·7
Blow gas, generator to carburettor main	645
,, ,, base of carburettor	820
,, ,, base of superheater	825
,, ,, top of superheater	680
,, ,, inlet waste heat boiler	660
Waste gas, outlet waste heat boiler	280
Oil, inlet to carburettor	51·5

TABLE V.—*Steam to Generator and Auxiliary Plant.*

	In Lbs. per 100 C.Ft. C.W.G.	Per Cent.
Total steam to set*	32·83	100·0
1. Steam to fuel bed during up-run	15·94	48·5
2. Steam to fuel bed during back-run	12 23	37·3
3. Steam to fuel bed during purge	1·14	3·5
4. Steam left in carburettor and superheater at end of back-run	2 64	8·0
5. Steam unaccounted for (difference)	0·88	2·7
	32·83	100 0
Total steam to set* decomposed per cent.		60·8
Steam to fuel bed during up-run ,,		84·5
Steam to fuel bed during back-run ,,		48·4
Steam to fuel bed during purge ,,		50·8
Total steam to fuel bed ,,		68·2
Rates of steam supply to fuel bed in lbs. per minute—		
During up-run		84·4
During back-run		158·3
During purge		84·4
Average throughout run period		100·6
Rates of steam supply to fuel in lbs. per minute per square foot of generator cross-section—		
During up-run		1·86
During back-run		3·49
During purge		1 86
Average throughout run period		2·22
Steam to auxiliary plant in lbs. per 1000 C.Ft. C.W.G.—		
Steam to turbo-blower	18·49	
Steam to exhauster	8·31	
Steam to oil pump	2·33	
Steam to boiler feed pump	3·53	
Steam to hydraulic pump	5·37	
Steam to "steam curtain" at inlet waste heat boiler	1·13	
Total steam to auxiliary plant		39·16

* Steam to auxiliary plant not included.

TABLE VI.—*Volumes of Air Supplied and Gas Produced and Rates of Supply and Production.*

Volumes in cubic feet per 1000 c.ft. C.W.G.—		
(*a*) Total blue gas produced		849
Blue gas produced during up-run	544	
Blue gas produced during back-run	243	
Blue gas produced during purge	26	
Blow gas accompanying blue gas	36	
		849
(*b*) Total air supplied to plant		2450
Air to generator	1834	
Air to carburettor	616	
		2450
(*c*) Blow gas produced		2034
(*d*) Waste gas produced		2544
Rates in cubic feet per minute (average)—		
1. Carburetted water gas during "run" periods		3,130
2. Blue water gas during "run" periods (average)		2,660
Blue water gas during up-run		2,360
Blue water gas during back-run		2,900
Blue water gas during purge		1,790
3. Air to generator during "blow" periods		7,400
4. Air to carburettor during "blow" periods		2,640
5. Blow gas produced during "blow" periods		8,200
6. Waste gas produced during "blow" periods		10,250
Rates in cubic feet per minute per square foot of generator cross-section—		
1. Blue water gas during "run" periods (average)		58·6
Blue water gas during up-run		52·1
Blue water gas during back-run		63·9
Blue water gas during purge		39·5
2. Air to generator during "blow" periods		163·0
3. Blow gas produced during "blow" periods		181·0

TABLE VII.—*Analyses of Coke, Oil, Ashes and Clinker, Fliers, and Tar. (Dry Samples.)*

Coke—	Proximate analysis—	
	Volatile matter	1·8
	Fixed carbon	89·3
	Ash	8·9
		100·0
	Ultimate analysis—	
	Carbon	87·7
	Hydrogen	0·4
	Sulphur	1·6
	Ash	8·9
	Nitrogen and oxygen (difference)	1·4
		100·0
	Calorific value (gross) in B.Th.U. per lb. (determined)	12,910
Oil—	Ultimate analysis—	
	Carbon	86·9
	Hydrogen	12·7
	Sulphur	0·3
	Ash	0·0
	Nitrogen and oxygen (difference)	0·1
		100·0
	Constituents of oil—per cent. by vol.*—	
	Paraffin hydrocarbons	53·3
	Unsaturated ,,	5·4
	Aromatic ,,	22·1
	Naphthene ,,	16·6
	Residue above 380° C.	2·6
		100·0
	Specific gravity of oil at 15·5° C.	0·855
	Calorific value (gross) in B.Th.U. per lb. (determined)	19,640
Ashes and clinker—	Ultimate analysis—	
	Carbon	19·9
	Hydrogen	0·1
	Sulphur	0·5
	Ash	79·1
	Nitrogen and oxygen (difference)	0·4
		100·0
	Calorific value (gross) in B.Th.U. per lb. (calculated)	2895

* The method of oil analysis will be published in a later report.

TABLE VII. (*continued*).

Fliers—	Ultimate analysis—	
	Carbon	84·6
	Hydrogen	0·3
	Sulphur	1·5
	Ash	12·2
	Nitrogen and oxygen (difference)	1·4
		100·0
	Calorific value (gross) in B.Th.U. per lb. (determined)	12,440
Tar recovered—	Ultimate analysis—	
	Carbon	90·5
	Hydrogen	7·2
	Sulphur	0·7
	Ash	0·0
	Nitrogen and oxygen (difference)	1·6
		100·0
	Calorific value (gross) in B.Th.U. per lb. (determined)	17,670
	Specific gravity at 15·5° C.	1·040

Distillation Test of Dehydrated Tar.

First drop	110° C.
Fractions as per cent. volume of dry tar—	
Below 170° C.	1·5
170—230° C.	13·5
230—270° C.	34·3
270—350° C.	26·2
Pitch (by difference)	24·5
	100·0
Analysis of ash from "Ashes and Clinker"—	
SiO_2	42·6
Al_2O_3	31·0
Fe_2O_3	16·2
CaO	5·8
MgO	2·3
SO_3	1·3
Loss + alkalies (difference)	0·8
	100·0
Softening temperature	1180° C.

TABLE VIII.—*Carbon Balance of Production of Carburetted Water Gas.*

—	In Lbs. per 1000 C.Ft. C.W.G.	Per Cent.
Carbon supplied—		
(*a*) Coke to generator	29·88	65·58
(*b*) Oil to carburettor	15·68	34·42
	45·56	100·00
Accounted for as follows—		
1. Carburetted water gas	22·14	48·60
2. Ashes and clinker	0·78	1·72
3. Fliers	0·38	0·83
4. Tar	4·40	9·65
5. Waste gas and carbon unaccounted for (difference)	17·86	39·20
	45·56	100·00

TABLE IX.—*Carbon Balance of Generator.*

—	In Lbs. per 849 C.Ft. of Blue Water Gas.*	Per Cent.
Carbon supplied—		
(*a*) Coke to generator	29·88	99·83
(*b*) Carbon gasified in carburettor and superheater by back-run steam	0·05	0·17
	29·93	100·00
Accounted for as follows—		
1. Blue water gas	12·31	41·13
2. Ashes and clinker	0·78	2·61
3. Fliers	0·38	1·27
4. Blow gas and carbon unaccounted for (difference)	16·46	54·99
	29·93	100·00

* 849 c.ft. of blue water gas are equivalent to 1000 c.ft of C.W.G.

TABLE X.—*Carbon Balance of Oil to Carburettor.*

—	In Lbs. per 1000 C.Ft. C.W.G.	Per Cent.
(*a*) Oil to carburettor	15 68	100·0
Accounted for as follows—		
1. Carbon in oil gas	9·83	62·7
2. Tar	4·40	28·1
3. Carbon gasified in carburettor and superheater by back-run steam	0·05	0·3
4. Carbon in waste gas and unaccounted for (difference)	1·40	8·9
	15·68	100·0

TABLE XI.—*Steam Raised in Generator Boiler and Waste Heat Boiler.*

—	Generator Boiler.	Waste Heat Boiler.
Water supplied to boiler, total in lbs.	281,000	373,500
Temperature of feed water, degrees C.	60 1	60·1
Pressure of steam in boiler, lbs. per sq. in. (average)	30·5	98·0
Water "blown down" from boiler, total in lbs.	24,150	34,150
Water "blown-down" in lbs. per 100 lbs. feed water	8·6	9·1
Temperature of water "blown-down" from boilers, degrees C.	135·0	154 0
Water evaporated in lbs. per 1000 c.ft. C.W.G.	26·9	35·6
Equivalent evaporation in lbs. from and at 100° C. per 1000 c.ft. C.W.G.	29·2	38·2
Equivalent evaporation in lbs. from and at 100° C. per lb. of dry coke to generator	0·77	1·21
Heat in B.Th.U. required for evaporation per 1000 c.ft. C.W.G.	28,300	37,050
Dryness fraction of steam	0 99	0·95

Steam raised and used in lbs. per 1000 c.ft. C.W.G.—	
Steam raised in generator boiler at 30·5 lbs. per sq. in.	26·9
Steam raised in waste heat boiler at 98·0 lbs. per sq. in.	35·6
Total steam raised	62·5
Total steam to generator	32·8
Total steam to auxiliary plant	39·2
Total amount of steam supplied to generator and auxiliary plant	72·0
Steam required from independent source	9·5
Amount of coke required to raise 9·5 lbs. of steam in independent boiler of 70 per cent. efficiency, in lbs.	1·24
Amount of heat as coke required to raise 9·5 lbs. of steam in independent boiler of 70 per cent. efficiency in therms per 1000 c.ft. of C.W.G.	0·161

TABLE XII.—*Heat Balance of Production of Carburetted Water Gas.*

—	In Therms per 1000 C.Ft. C.W.G.	Per Cent.
Heat supplied—		
(*a*) Coke to generator, heat of combustion	4 399	52 84
(*b*) Oil to carburettor, heat of combustion	3·552	42·66
(*c*) Oil to carburettor, sensible heat	0·000	0 00
(*d*) Air to blower, sensible heat	0·005	0·06
(*e*) Total heat of steam to set*	0·370	4·44
	8·326	100 00
Accounted for as follows—		
1. Carburetted water gas, potential heat	5·030	60·41
2. ,, ,, ,, sensible heat	0·292	3·51
3. Steam not decomposed, total heat	0·192	2 31
4. Tar, potential heat	0 860	10 33
5. ,, sensible heat	0·036	0·43
6. Waste gas, potential heat	0·519	6·23
7. ,, ,, sensible heat	0·286	3·43
8. Heat to raise steam in generator boiler	0·283	3·40
9. ,, ,, ,, ,, ,, waste heat boiler	0·371	4·46
10. Heat supplied to water "blown-down" from boilers	0·001	0·01
11. Ashes and clinker, potential heat	0·100	1·20
12. ,, ,, ,, sensible heat	0·002	0·02
13. Fliers, potential heat	0·057	0 69
14. ,, sensible heat	0·000	0·00
15. Losses not separately determined, leakages, radiation, convection, &c. (difference)	0·297	3·57
	8·326	100·00

* Steam to auxiliary plant not included.

TABLE XIII.—*Heat Balance of Generator.*

—	In Therms per 849 C.Ft. B W.G.*	Per Cent.
Heat supplied to fuel bed—		
(*a*) Coke to generator, heat of combustion	4·399	91·29
(*b*) Total heat of steam to generator†	0·399	8·28
(*c*) Sensible heat of air to generator	0·004	0·08
(*d*) Potential heat of gas from carbon on chequer bricks	0·016	0·33
(*e*) Sensible heat of gas from carbon on chequer bricks	0·001	0·02
	4·819	100·00
Accounted for as follows—		
1. Blue water gas, potential heat	2·471	51·27
2. ,, ,, ,, sensible heat	0·167	3 47
3. Steam not decomposed, total heat	0·146	3·04
4. Blow gas, potential heat	1·018	21·11
5. ,, ,, sensible heat	0·519	10·77
6. Ashes and clinker, potential heat	0·100	2·08
7. ,, ,, ,, sensible heat	0·002	0·04
8. Fliers, potential heat	0·057	1·19
9. ,, sensible heat	0·000	0·00
10. Heat to raise steam in generator boiler	0·283	5·87
11. Heat supplied to water "blown-down" from boiler	0·000	0·00
12. Losses not separately determined, leakage, radiation, convection, &c. (difference)	0·056	1·16
	4·819	100·00

* 849 c.ft. blue water gas are equivalent to 1000 c.ft. carburetted water gas.

† Steam left in carburettor and superheater at end of back-run and the steam to auxiliary plant not included.

TABLE XIV.—*Heat Balance of Carburettor, Superheater, and Waste Heat Boiler.*

—	Therms per 1000 C.Ft. C.W.G.	Per Cent.	Heat Quantities expressed as a Per Cent. of the Heat contained in Blow Gases Leaving Generator.
Heat supplied—			
(*a*) Oil to carburettor, heat of combustion	3·552	50·66	
(*b*) ,, ,, sensible heat	0·000	0·00	
(*c*) "Up-run and purge" blue gas, potential heat	1·743	24·85	
(*d*) "Up-run and purge" blue gas, sensible heat	0 129	1·84	
(*e*) "Up-run and purge" steam, not decomposed	0·051	0·73	
(*f*) Blow gas, potential heat	1·018	14·51	100·00
(*g*) ,, ,, sensible heat	0·519	7·40	
(*h*) Air to carburettor, sensible heat	0·001	0·01	
	7·013	100·00	
Accounted for as follows—			
1. Carburetted up-run gas,* potential heat	4·313	61·52	
2. ,, ,, ,, * sensible heat	0 263	3·75	
3. "Up-run and purge" steam, not decomposed	0 052	0·74	
4. Tar, potential heat	0·860	12·27	
5. ,, sensible heat	0·036	0·51	
6. Waste gas, potential h at (outlet boiler)	0·519	7·40	33·78
7. ,, ,, sensible heat (outlet boiler)	0·286	4·08	18·62
8. Heat to raise steam in waste heat boiler	0 371	5·29	24·15
9. Heat supplied to water "blown-down" from boiler	0·001	0·01	
10. Heat supplied to back-run steam entering generator	0·061	0·87	3·97
11. Potential heat of gas from carbon on chequer bricks	0·016	0·23	1·05
12. Sensible heat of gas from carbon on chequer bricks	0·001	0·01	0·04
13. Heat supplied to steam left in carburettor and superheater at end of back-run	0·015	0·21	0·96
14. Losses not separately determined, radiation, convection, &c.	0·219	3·11	
	7 013	100·00	

* Includes "purge" blue gas.

TABLE XV.—*Heat Balance of Waste Heat Boiler.*

—	In Therms per 1000 C.Ft. C.W.G.	Per Cent.
Waste heat boiler—		
1. Total heat of steam raised	0·371	30 9
2. Heat supplied to water "blown-down" from boiler	0·001	0·1
3. Waste gas, potential heat	0·519	43·2
4. Waste gas, sensible heat at outlet boiler	0·286	23·8
5. Losses, radiation, convection, &c. (assumed)	0·025	2·0
6. Total heat entering boiler (Total heat entering boiler calculated from heat of blow gas at inlet boiler = 1·16 therms)	1·202	100 0

Thermal efficiency of boiler per cent.

$$= \frac{\text{item (1)} \times 100}{\text{item (6)}} = 30{\cdot}9 \text{ per cent.}$$

Generator boiler—	
Coke to generator in lbs. per 1000 c.ft. C.W.G.	34·08
Heat to raise steam in generator boiler in therms per 1000 c.ft. C.W.G.	0·283
Lbs. of coke required to raise steam in a boiler of 70 per cent. efficiency	3·13
Coke to generator in lbs. per 1000 c.ft. C.W.G., making allowance for the steam raised in generator boiler	30·95

TABLE XVI.—*Heat Values of Oil and Products.*

—	Therms per 1000 C.F. C.W.G.	Per Cent.
Oil to carburettor	3·552	100·00
Products—		
Oil gas	2·559	72·04
Tar	0·860	24·22

Gallons of oil used per 1000 c.ft. C.W.G.	2·11
Therms in 1000 c.ft. C.W.G.	5·030
Therms in 849 c.ft. B.W.G.	2·471
Increase due to oil	2·559
"Therms per gallon of oil"	1·21

DISCUSSION.

The PRESIDENT: I think you will agree that this is an extremely valuable report, and one worth while taking home for study, because it contains so much information which obviously can easily be put to practical use, I think with very beneficial results.

PRACTICAL ADVANTAGES OF BACK-RUN PLANT.

Mr. E. J. HUTCHENCE (Gas Light and Coke Company, Stratford Works): Dr. Dent's report was so complete that there seems very little left for the man to say who was in charge of the plant. However, perhaps I may call attention to the practical advantages of a back-run plant. The most important point seems to be that with the back-run process the steam enters the fuel bed at a temperature of 650° C. The advantage of this is seen if we compare our results with those of the Sixth Report on blue water gas, where the steam decomposed was 56 p.ct., in the Seventh Report on carburetted water gas it was 53 p.ct., whereas Dr. Dent's figure for steam decomposed is 60·8 p.ct., or an improvement of 15 p.ct. on the figure in the Seventh Report. The results per 1000 lbs. of coke or pounds of coke per 1000 c.ft. are correspondingly good. The Stratford result was 72·2 therms per 1000 lbs. of coke or 34 lbs. of coke per 1000 c.ft.; allowing for the steam raised in generator boiler it was 31 lbs. of coke per 1000 c.ft., whereas the Seventh Report of the Gas Investigation Committee, 1921-22, gave 35-36 lbs. of coke per 1000 c.ft. We used a large gallonage of oil (2·11 gallons) and the heating power of the gas was 503; taking the heating power of 1 gallon at 1·4 therms this showed a cracking efficiency of 86·4 p.ct., which may be considered good in view of the large amount used. The dry tar recovered was 22 gallons per 100 gallons of oil; this compared with only 14-16 gallons as quoted in the Seventh Report, and here I would put on record the great pains that Dr. Dent took to get this knotty question accurately answered.

A most interesting figure is that of carbon in the clinker; Dr. Dent found only 20 p.ct. against 48 p.ct. of the Seventh Report. I think these few figures showing the progress made during the last ten years are very encouraging.

These back-run automatically operated rotary grate sets have been in continuous use since November, 1928 (two years), and there have been no major repairs to them whatever; and it is of interest to note that our wear and tear expenditure for the nine months of the current year on the whole of our oil gas plant, including the house, the whole of the generating plant and boilers, the condensers, the tar washers, the exhausters and pumps and the gasholders, is at the rate of only 0·6d. per 1000 c.ft.

I think I ought to refer also to the coke used in Dr. Dent's test. Shortly before his test, we were using a coke from one Yorkshire coal only, carbonized in verticals which gave much trouble with clinker. In order to ensure accurate and steady results during the test we took a coke from a mixture of Durham coals carbonized in horizontals, but I would emphasize that before and since this test we worked, and are now working continuously, with coke from mixed Yorkshire coals carbonized in vertical retorts, and our results are substantially the same as those which Dr. Dent has presented to you.

STEAM GENERATION.

Mr. T. F. E. RHEAD (Birmingham) I should like to thank the Research Committee for this very timely report. It so happens that in Birmingham we are just about to start up two of these automatic water gas plants, each to make about 2¾ million c.ft. per day, so that you will appreciate that this report is very useful to us. The gas undertakings in London are more familiar with the automatic plant than we are, and probably a few of the questions I shall ask will appear to them to be very simple. It is very useful to know that from the point of view of heat saving the back-run process does not appear to have any advantage over the other process, but it will be extremely useful to know, as work goes on, to what extent the capacity of the plant is increased due to sweeter working of the generator occasioned by the use of the back-run. With regard to the figure of 22·02 gallons of dry tar (Table I.), that seems to me to be rather high. If I remember aright, when Dr. Parker carried out his work at Windsor Street, he obtained 15 gallons; it was measured extremely carefully, and that figure did represent the total amount of tar produced by that process. The figure in this report rather suggests that the tar is not cracked to the same extent in the back-run process as in the old one, due, presumably, to having to rush it through in a shorter period. I was very interested in the relative figures of the steam generated in the generator boiler and the waste-heat boiler—29·2 units in the generator boiler as compared with 38·2 units in the waste-heat boiler. It seems a remarkably large percentage of steam from the generator boiler. There is also in Table I. an item for extra steam. I have always understood that these generator sets were entirely self-steaming and I should like a little enlightenment on that point. Another interesting point is that in Table II. the volume p.ct. of total blue gas is 64·1 on the up-run and 28·6 on the back-run. It would appear that the rate of gas production per unit time is greater with the back-run than with the ordinary orthodox up-run. Again, the amount of H_2S in grains per 100 c.ft. seems very high in the back-run—*i.e.*, 448 per 100 c.ft.—as compared with 141 per 100 c.ft. in the up-run. The grains of sulphur in the blow gas as sampled between generator and carburettor are 36 per 100 c.ft., and in the waste gas on the outlet waste-heat boiler it is 58 grains per 100 c.ft.

NOT YET PROVEN.

Dr. A. PARKER: In the first place I must congratulate Dr. Dent and his assistants on carrying this work through so well. I know from past experience that it is not an easy matter to examine a plant having so many complications as a carburetted water gas plant, especially with back-run and waste-heat boiler, and to find at the end of your first test that you have really got figures that balance even approximately. Every detail has to be watched, especially when you are making a gas such as blue water gas in the generator, varying considerably in composition throughout the whole cycle. I am sure the Research Committee has come to a right decision in deferring any definite conclusions as to the real value of the back-run. The real value cannot be determined merely by comparison of the results of this test with those given in the Seventh Report, because there are so many other differences in procedure. Undoubtedly, the proper method is to carry out tests on a plant which may be operated both with the back-run process and without it. The results given in this report are remarkably close to those given in the Seventh Report as regards thermal efficiencies, but there are differences in output of plant when calculated per square foot of grate area. That is quite understandable. In making water gas, either blue or carburetted, certain cycles of operation have to be adopted, and the cycles are chosen with consideration to human power in operating valves at given times—as to how accurately a man can time the operation of valves—and considerations such as the period occupied in clinkering, where this is done by hand, and, at the same time, the period required for purging the plant in changing from blow to run and from run to blow. The limiting factor in the hand-operated plant is obviously the human factor, but with automatic clinkering and automatic operation of valves the total period for a complete cycle can be reduced, and this is a move in the right direction. The ideal would be to have a blow period of only a few seconds and a run period of only a few seconds, so far as the temperature conditions of the generator are concerned, but we cannot arrive at such ideal conditions as those because of the necessity for purging the plant. In the test described in this report, the complete cycle occupied about three minutes, as compared with

about six minutes in the tests referred to in the Seventh Report. The output of the plant is controlled also by the velocity with which air is blown through the bed of fuel during the blow period. The only limiting factor in the raising of that velocity is that red hot coke must not be blown out of the generator, and I have no doubt that in the tests described in the Seventh Report the output per square foot of grate area could have been increased if required by increasing the velocity of air during the blow period and increasing the velocity and amount of steam per minute in the run periods. Therefore, I would warn the investigators against trying to draw too many conclusions from a comparison of output of the plant described in the Seventh Report and that described in this 27th Report. Mr. Hutchence gave figures for the efficiency of steam decomposition as quoted in the Seventh Report and compared them with the figures in the 27th Report, and I understood from him that the efficiencies of decomposition of steam were much larger in these later tests. I have not yet had time to study this report carefully in conjunction with the Seventh Report, but my recollection is that the efficiency of decomposition of steam, quoted in the Seventh Report, approached 70 p.ct., and that is almost identical with the figures given in this 27th Report. Was Mr. Hutchence confusing figures of over-all thermal efficiency with the figures given for percentages of steam decomposed?

The main point seems to be that improvements are attained by self-clinkering grates and by automatic operation of the plant, but I do not consider it yet proven that there is any distinct advantage in the back-run process, especially if it means a reduction in the amount of steam raised in the waste-heat boiler following the superheater. No doubt, however, the tests which are to be carried out on a plant which can be operated in both ways will provide an answer to this question.

Mechanically Operated Grates.

Mr. C. M. D. Belton (Shrewsbury): At the end of Section (*b*) of the paper it is stated that, with a shorter cycle, the high temperature attained in the fuel bed at the end of the blow, and the accompanying formation of clinker, should be reduced. Dr. Parker said he did not think that there was any advantage in the back-run. From my experience I can corroborate the suggestion made in this report that there is a definite advantage due to the use of the back-run, owing to the fact that the temperature variation throughout the plant is not so great. It would have been interesting if a chart had been given showing the variations in temperature throughout the plant on the time basis. Some reference is also made in Section (*c*) of the paper to the operation of the automatic grate, and an advantage is claimed for this; but I notice a statement to the effect that it was found necessary to inspect the fire once per shift of eight hours, and that this inspection occupied 13 minutes on the average. In our experience we have found that a period of 16 minutes, once in eight hours, is all that is required to clinker the generator by hand, so that it seems that not much time is gained by the use of a mechanically operated grate. With regard to the coke, I notice that it contains rather a high percentage of moisture—4·1 p.ct. This is probably due to the fact that the coke is from horizontal retorts; the percentage of moisture in vertical retort coke is very much less. Then there is the problem of fliers. At many works, such as my own, it is necessary to take particular care to avoid the deposition of fliers, and even finer grit, outside the works, owing to the proximity of other premises; but we find that by the careful forking of screened coke we are able to reduce the amount very considerably, and with the back-run process we have found less than half the usual amount of fliers deposited in the form of mud in the wash-box, and it would appear that it is well worth while to use screened coke and to fork it well before using it in the generator. The economy, not only in the actual carbon available for conversion, is quite evident. I am speaking now from experience.

I should like to add that we are looking forward with very great interest to the forthcoming report of the results of comparative tests on plants in parallel, or on the same plant working both processes. That report will be extremely useful to us. I should also like to thank the authors of this extremely useful 27th Report.

Effect of Oil Quality.

Dr. S. Pexton: Reference has been made to the smaller variation of temperature in the fuel bed due to the reduction of the length of the cycle resulting from the use of mechanical operation. I venture to think that there has been very little difference between the temperatures of the fuel beds in the Stratford test and in the tests recorded in the Seventh Report, because, although the cycle in the Stratford test was much shorter than the cycle adopted at Birmingham, the quantity of steam introduced per run—as distinct from per unit of time—is practically the same in both cases. I think that it is not the length of time which controls the temperature in the fuel bed, but rather the quantities of air and steam admitted during the cycles. Some comment has been made on the very high yield of tar obtained at Stratford as compared with the yield obtained at Birmingham. I do not think there is any doubt about the measurements made either at Birmingham or at Stratford; I think the difference is due largely to the difference in the quality of oil. We have made measurements of the tar yield on a hand-operated set similar to that used at Birmingham without the back-run process, and have obtained about 23 or 24 p.ct. of tar, measured on the basis of the oil. Some comment has been made also on the percentage of steam decomposed. In Table C I think there is a slight error. The percentage of steam decomposed in the test described in this report is given as 68 p.ct., whereas in Table I. the percentage of steam decomposed is given as 60·8 p.ct. This seems to answer to some extent the question raised by Dr. Parker. I believe he is right in stating that the percentage of steam decomposed, as stated in the Seventh Report, was practically 70 p.ct., and I think the percentage of steam decomposed in the test recorded in this 27th Report is rather lower than in the tests recorded in either the Seventh or the Tenth Report.

Methods of Sampling.

Mr. Williams (representing Dr. J. G. King, of H.M. Fuel Research Station): There are one or two matters referred to in this report about which I should like to be certain, and I hope that I shall not be regarded as being too critical. It is stated in Section (*e*) of the report, where reference is made to the sampling of blue gas and blow gas, that "in taking a sample either for analysis or for the determination of the amount of undecomposed steam, true average figures are only obtained if the rate of sampling varies directly as the rate of production of the gas to be sampled. It was impracticable to devise an apparatus which would permit of such sampling. . . ." A little later in the report, where reference is made to the calculation of volumes of blue gas produced, we are told that use has been made of an average sample of gas collected over the different phases of the cycle. Evidently, if this volume of gas collected during any phase is not truly representative of the rate of production of the gas over that particular phase, then the calculation of the volume of blue water gas produced in a particular phase should reflect a corresponding error. It seems to me that surely a method can be found whereby resort to a calculation of this description would not be necessary. As a matter of fact, we are also doing some work on water gas production at the Fuel Research Station, and we have a method whereby, by means of a suitable orifice plate placed in the gas main, and using an ordinary inclined gauge for recording pressure differences across the orifice, we can, by photographically measuring the movement of the meniscus in an inclined gauge, determine correctly the amount of blue water gas produced during an up-run, or back-run, or any other run you like. In this way we get a record of the gas made at any particular point of the cycle or for any particular period.

I am also inclined to bring up the old bogey against all water gas tests. I do feel that it is time we determined the amount of blow gas or the amount of carbon utilized in the blow gas directly. Here again, by means of suitable orifice plates, calibrated against Pitot tubes, and by means of a sensitive recording diaphragm gauge, we can calculate directly the amount of air utilized in a particular blow period. We find, when using this method against the ordinary carbon difference method, in all circumstances there is a difference of from 2 to 5 p.ct. We do not claim that the orifice plate method of measuring the amount of air produced is accurate to within less than 2 p.ct., but we do claim that the errors which occur in sampling, measurement, and calculation in the carbon difference method are all included in the figure representing the volume of blow gas produced, and this necessarily means an error in the figure for the amount of heat produced during the process. If the amount of air utilized during the process could be measured directly, we should have a check as between the amount of carbon consumed, as measured by the orifice plate method and the difference method. I would respectfully suggest to the investigators that in further work they do they should use means whereby the figure representing the amount of carbon utilized in the blow gas, and as obtained by the difference method, should be checked by measurement of the amount of air directly consumed.

Proving or Disproving Claims.

Mr. F. Nicholls (Newcastle-on-Tyne): In the commercial exploitation of several types of gas apparatus claims are made which doubtless form very attractive selling points for use by the salesmen concerned, but which it is very difficult for the gas engineer to prove or disprove in advance. He may prove or disprove those claims when he has the plant, but it may be too late then. Some of the claims, however, cannot be proved even then to his satisfaction. One such claim is that a plant is self-supporting in the matter of steam. I think the report is valuable in that it gives us an indication as to whether that claim is valid or not. My own experience suggests that it is far from being valid. The figures in the report suggest that 85 p.ct. of the total steam required is supplied by the plant, but I think this figure is rather high. During the first few hours after starting-up a plant of that type there is a very big demand on the boilers, and this has to be considered if it is the intention to use the water gas plant for comparatively short periods only. If the plant is running fairly steadily, however, the amount of steam taken from the works supply is still appreciable, and I

find that it means the addition of at least one other boiler in the works. The steam supplied by the plant will be sufficient for all that is required for gas-making proper, but will not be sufficient to supply all that is required for ancillary plant—blowers, and so on.

Maintenance Costs.

In regard to maintenance costs, comments have been made with regard to the low quantity of carbon in the clinker. I think this is a case in which high technical efficiency may mean the very reverse of economy. The self-clinkering grate works very sweetly on a mixture of clinker and coke, if there is a fair percentage of coke present, but if you attempt to cut down the quantity of coke and to work almost exclusively on clinker you will experience a lot of trouble; a considerable strain is thrown on the grate in those circumstances, and I think it is as well not to strive after too low a carbon content in the clinker.

As to back-run steaming, I rather favour the view that the case for it has not been made out. Reference is made to the very high rate of steaming during the back-run process. To a certain extent that is a practical problem. We have a cycle of only 2 minutes, of which 60 seconds is available for gas-making. In that period of 60 seconds there are about 9 or 10 valve operations, and the period left for back-run steaming is very short. Therefore, it is necessary to steam at a very high rate, and this involves another danger—*i.e.*, in regard to control of steam. In the ordinary up-run process, if there is too much steam, the CO_2 figure is increased. The disadvantage of the back-run process is considerable overheating of the self-clinkering grate if there is too much steam, so that the grate will be damaged, it will be troublesome to repair, and your maintenance costs will increase very quickly. The repair of the grate will involve the dismantling of practically the whole of the plant.

Therefore, on the whole, this report is valuable, in that it draws attention to the questions as to whether it is worth while striving after low carbon content in the clinker, and whether or not the back-run process is as valuable as it has been claimed to be; while it also shows that the claim that the plant is self-supporting in the matter of steam is not fully borne out.

Mr. T. Reynolds (Blackpool): I should like to refer to the difficulties in the back-run process with sticky valves. I had the opportunity of fixing the back-run process at Blackpool, and it was a source of annoyance continually to have the valves stuck. One was a vertical valve on the back-run pipe and the other a horizontal valve on the forward-run pipe. After a while I dispensed with the valves altogether and fitted two single-faced horizontal valves on the top side of the seal box. On the top of the single-face valves we fitted a water supply which was continually running on to these valves during the reverse run of the gas, so that it was always water-sealed and kept cool. Reversing the valves, the water was immediately sent down into the seal box. Another point I should like to mention is that one speaker said that the back-run process had not been explained in detail that it was successful. The plant I have been referring to had a nominal capacity of 700,000 c.ft. and on fixing the back-run process to it the capacity was increased to 1,300,000 c.ft. without any structural alterations other than the fans of the back-run process. It was also found that the superheater was kept much more free, as the carbon deposit in the top of the superheater was turned back into gas. I thought I would take the opportunity of mentioning these two facts.

The President: We have had a very instructive and valuable discussion on the back-run process. My own experience of it is that the wear and tear on the plant is distinctly heavy, but, notwithstanding that fact, the financial advantages accruing from its operation, as compared with one of the ordinary water gas plants, are most marked; I know this as the result of a considerable period of working, and there can be no question about the financial advantages. I have been astonished to hear of the high percentage of carbon in the clinker. I work my grate only 50 p.ct. of the time, and I have no difficulty in getting the carbon content in the clinker down to 12 p.ct. In regard to wear and tear, I find that the back-run valve is the most troublesome part of the plant, owing to the conditions to which it is subjected. I believe that if the valve could be constructed of some other material than that which is used, a great saving would be effected in maintenance costs.

Dr. Dent Replies.

Dr. Dent, replying to the discussion, said: I should like to thank the meeting for the manner in which this report has been received, and especially those engineers who have discussed the back-run process from the practical point of view. The principal question raised appears to be whether or not it is worth while taking heat back to the generator, as this cuts down the performance of the waste-heat boiler. I think the point there is that the same amount of heat that is taken back in the back-run steaming can be used much more efficiently in the generator—approximately 2 or 3 times as efficiently—than in the waste-heat boiler. The generation of heat in the generator itself by blowing air through it is a very inefficient process. Most of the heat is lost in the blow gases, and if all that heat is regarded as lost the process is less than 30 p.ct. efficient. Normally, some of this heat is recovered in the carburettor, superheater, and waste-heat boiler, but this does not bring the efficiency of the process up to 50 p.ct. I think that is the real point in regard to taking heat back to the generator by back-run steam.

Reference has been made by Mr. Rhead to the large quantity of tar which we obtained. Dr. Pexton has carried out tests in which the percentage of tar obtained is similar to that stated in the report, and also, in our own laboratory experiments on the cracking of gas oil, some of the results indicated that it was quite possible to obtain a thermal yield of oil gas of over 1·3 therms per gallon, and yet to have as much as 25 p.ct. of tar—which is very similar to the amount we measured in the test. Mr. Rhead also mentioned the high percentage of H_2S in the back-run. We had not time to follow up that matter by further investigations, but the figure was one which we could duplicate, and it was, in fact, duplicated during the test. It is put forward now as a matter of interest; and we hope, in the course of our further work, to investigate the point. I believe that in America it has been observed that the back-run steaming does tend to reduce the presence of organic sulphur and to increase the amount of H_2S present in the gas. Similar remarks apply to the figures relating to SO_2. The period of clinkering, as stated in the report, and which almost equals the period of clinkering that Dr. Parker observed in his tests, was measured by noting the time during which the automatic operator was stopped during the clinkering.

The point has been raised by Dr. Pexton that, since the rate of steam supply was greater in the tests now described than in the tests recorded in the Seventh Report, the shorter cycle used did not cut down the variations of temperature in the fuel bed during different parts of the cycle. Perhaps it would have been better to have stated in the report that a shorter cycle—other things being equal—would have led to less fluctuation in the temperature of the fuel bed. It can be accepted that the shorter cycle does enable higher rates of steaming to be employed without increasing the fluctuations of temperature in the fuel bed. Dr. Pexton also referred to the figures in Table C, and suggested that the item "Steam to fuel bed decomposed p.ct." should be 60·8 instead of 68, so that it would agree with the figure in Table I. Actually, however, that figure represents the percentage of the steam which actually passed through the fuel bed. It does not include the amount of steam which was left in the carburettor and superheater at the end of the back-run, or the amount of steam which leaked past the valves. Similar remarks apply to the figure immediately above it—"Average rate of steam supply to fuel bed during run periods in lbs. per minute," which was 100·6. That means the amount of steam which actually passed through the fuel bed, and I think the figures agree with the figures given in Table V. The total steam *to set* decomposed p.ct. is 60·8, but the total steam to fuel bed decomposed p.ct. is 68·2.

25th Report of the Joint Research Committee of the Institution and Leeds University

Examination of the Products of Combustion from Typical Gas Appliances—Part V.

Research Chemist: J. W. Wood, M.Sc. (Tech.), A.I.C.

[Summary.]

This report is a continuation of the 15th, 17th, and 19th Reports of the Gas Investigation Committee and the 21st Report of the Joint Research Committee, and deals with the products of combustion from gas appliances, with special regard to carbon monoxide.

The small amounts of CO present have been determined on 5 to 10-litre samples throughout, using the iodine pentoxide method described in previous reports.

The appliances examined include a surface-combustion water-heater, the Fairweather calorimeter, and the inverted incandescent mantle burner.

The Appendix contains notes upon alternative methods for the determination of small amounts of CO. Some points of interest arising from a visit to the 1929 Gas and Water Exhibition in Berlin are also discussed.

The tests have all been carried out with town gas of a declared calorific value of 470 B.Th.U. per c.ft., as distributed from the Meadow Lane Gas-Works, Leeds.

Surface-Combustion Water-Heater.

The heating element consisted of a hollow cylinder of porous refractory material 4½ in. dia. and 15 in. long, placed in the combustion chamber of a small water heater (16 in. dia. and 3 ft. long). It was supplied by low pressure gas, and air under slight pressure from a small motor-driven fan. It was intended to consume 100 c.ft. of gas per hour, and to heat 40 gallons of water per hour through 100° F.

The mixture of gas and air burned on the outer surface of the cylinder, and the best conditions were obtained when the quantity of air used was just sufficient to remove visible flame from the surface of the combustor. This condition was easily recognizable, and corresponded with an excess of air 10 to 15 per cent. greater than that theoretically necessary for complete combustion of the gas.

At 100 c.ft. per hour the combustor surface attained a moderate red-heat, and at 140 c.ft. per hour a bright red-heat. With 10 to 15 per cent. excess air the CO production was less than 2 parts per 10,000 of gas burned, or 0·05 part per 10,000 in the exit gases from the appliance. With less than 5 per cent. excess air, a condition which ought not to arise in practice, because of the characteristic appearance of the combustor surface, the production of CO rose very rapidly. The thermal efficiency of the apparatus was about 80 per cent. on the gross calorific value of the gas used.

Fairweather Recording Gas Calorimeter Burner.

The Fairweather Recording Gas Calorimeter uses a special tubular burner working at a very low pressure. It was examined *in situ* to determine the completeness of combustion, and the possible escape of unburned gas from the lower end of the burner, which is open. It was not necessary to make tests at any gas rate other than 5 c.ft. per hour, at which the burner normally works.

There was a negligible amount of CO in the products of combustion whether the air-flow through the calorimeter was normal or was reduced until the air was only 15 per cent. in excess of that theoretically required for complete combustion of the gas.

The CO production was less than 1 part per 10,000 of gas burned, and was therefore comparable with that of other free-burning flames previously examined.

There was evidence of a very slight escape of gas from the open base of the burner, but this gas was completely burned as it passed over the flame in the combustion chamber.

Universal Inverted Incandescent Burner.

The investigations were made with a typical downward-injection universal inverted burner with plain ⅜-in. nozzle. (Burner No. 5, 13th Report.)

The tests were made with pressures up to 7 in. w.g., and over a range of gas rates from 1·5 to 8 c.ft. per hour, with various degrees of primary aeration.

With gas of the kind used in the tests (470 B.Th.U.) very satisfactory operating conditions for ordinary domestic use could be obtained at 2·5 in. w.g. and a gas rate of 5 c.ft. per hour.

In each of the succeeding groups of tests (except Group A) the gas-rate—CO-production curve is of a characteristic U-shape, with the CO figures covering a wide range of values. It is therefore convenient to divide each curve into three sections, corresponding with low gas rates (1·5 to 4 c.ft. per hour), normal working range (4 to 5·5 c.ft. per hour), and high gas rates (above 5·5 c.ft. per hour), respectively.

A.—*Inverted Burner without Mantle.*—These tests showed a CO production of 6·5 parts per 10,000 of gas burned at 3 c.ft. per hour, and 3·1 parts per 10,000 at 5 c.ft. per hour.

Both figures are negligibly small, but as the CO production for a typical Bunsen flame is only about 1 part per 10,000 of gas burned we must attribute the increase to the burning of the flame in an inverted position.

B.—*Inverted Burner with Bare Mantle, Normal Aeration.*—This group of tests was made between 3 and 6 c.ft. per hour, with the air shutter set for normal aeration at 5 c.ft. per hour.

Over the normal working range the CO production was 20 to 70 parts per 10,000 of gas burned. At 3 c.ft. per hour the CO production had risen to 150 parts per 10,000 of gas burned. The addition of the mantle therefore caused a very considerable increase in the output of CO, even though the primary aeration was practically the same as in the previous group of tests.

The tests quoted later show that some improvement could be effected by the use of a globe, but the improvement was mainly confined to the lower gas rates.

C.—*Inverted Burner with Mantle and Open Vitreosil Globe, Normal Aeration.*—The operating conditions at 5 c.ft. per hour would be regarded as good, and the flame was as hard as possible without creating objectionable noise. The primary aeration was slightly more than 50 per cent. of the theoretical air-requirement.

Over the normal working range of the burner the CO-output was 18 to 50 parts of CO per 10,000 of gas burned, rising to 114 parts per 10,000 as the burner was turned down, to 2·5 c.ft. per hour. In the extreme case where the gas rate was so far reduced that the flame was entirely within the mantle (1·5 c.ft. per hour), the CO production rose to 180 parts per 10,000 of gas burned. In the opposite direction, increase of the gas rate caused only a trifling increase in CO production, the figure for 8 c.ft. per hour being only 37 parts per 10,000 of gas burned.

D.—*Inverted Burner with Mantle and Open Vitreosil Globe, "Soft" Aeration.*—The primary aeration was reduced, and a slightly better light could be obtained over the range 3 to 4 c.ft. per hour, but at 5 c.ft. per hour and upwards the performance was less satisfactory than before. Despite the small hydrocarbon content and small air requirement of the gas, there was sooting of the burner nozzle at all gas rates, very marked below 4 c.ft. per hour.

Over the normal working range the CO production was

8 to 54 parts per 10,000 of gas burned. Below 4 c.ft. per hour the rise in CO production was very pronounced, more than 300 parts per 10,000 being obtained at 2 c.ft. per hour. Even at 8 c.ft. per hour and with flame escaping freely at the mantle-ring and licking up the burner nozzle, the CO production was only 30 parts per 10,000 of gas burned.

Up to 4 c.ft. per hour the advantage as regards smaller CO production clearly lies with the well-aerated flame. The curious result that between 4 and 8 c.ft. per hour the "soft" flame yielded a smaller CO production than the well-aerated flame was confirmed, but no satisfactory explanation is as yet forthcoming. The difference between the CO output in the two cases is small over this range, and the higher degree of aeration would, without question, be the better in view of the behaviour of the burner below 4 c.ft. per hour.

E.—*Inverted Burner with Mantle and Close Fitting Vitreosil Globe.*—A number of the tests were repeated with a closed silica globe with hemispherical bottom. This was perforated with six radial slots 1¼ in. long by ¼ in. wide. The supply of secondary air was thus restricted as compared with the open globe, but was still greatly in excess of requirements.

The CO production curve is much flatter than for the open globe, and intersects the other curves. At low and high gas rates the use of this globe effected an improvement as compared with the open globe, and it is therefore difficult to explain why the CO production over the normal working range of the burner should be slightly higher than before.

A CO production of 20 to 40 parts per 10,000 of gas burned would cover the range of 3 to 8 c.ft. per hour with this globe.

The following Table summarizes the results obtained in the tests.

Summary of Tests with Universal Inverted Incandescent Burner.

Gas Used: 470 B.Th.U. gross per c.ft. Requires 4 c.ft. of air per c.ft. gas.

CO-production in parts per 10,000 of gas burned.*

Gas Rate. C.Ft. per Hour.	Burner Pressure. Ins. W.G.	Without Mantle.	Bare Mantle.	Mantle and Open Globe.		Special Vitreosil Globe.
				Normal Aeration.	Soft Aeration.	
		A.	B.	C.	D.	E.
1·5	0·3			180	..	
2	0·4			145	310	
2·5	0·6			114	220	
3	0·9	6·5	150	88	150	50
3·5	1·2		100	66	96	42
4	1·6		70	48	54	37
4·5	2·0		40	33	27	33
5	2·5	3·1	26	22	14	28
5·5	3·1		20	18	8	23
6	3·8		16	18	9	21
7	5·3			24	18	18
8	6·8			37	29	20

* The CO concentration in the theoretical products of combustion without excess air) is about one quarter of the above values.

In considering the above figures it will be seen that the rate of CO production by the universal inverted incandescent mantle burner is considerably higher than that given by a free-burning flame (*circa* 1 part per 10,000 of gas burned). The amount of CO in the theoretical products of combustion frequently exceeds 4 parts per 10,000, or say 15 parts per 10,000 of gas burned.

The following considerations must be borne in mind, however:—

(1) The CO production is lowest over that range of gas rate at which the burner will normally be used.

(2) The gas rate, and hence the total amount of CO produced per burner per hour, is small, especially when compared with typical room capacities and ventilation (0·01 to 0·03 c.ft. of CO per hour between 4 and 5·5 c.ft. of gas per hour).

(3) The products of combustion will in every case be very greatly diluted before reaching breathing level, and the CO-concentration in practical operation will be harmless

The results obtained, however, show that, from the standpoint of economy, efficiency, and hygiene, it is not desirable to operate an incandescent mantle burner at a rate much below its normal working rate. Where a small light is required, satisfactory results will be obtained by installing a smaller unit, such as a No. 2 or a Bijou burner.

A Pyrographic Method of Examining the Flames of Gas Appliances.

If a sheet of white paper is held steadily in a horizontal position for a few seconds some inches above an ordinary

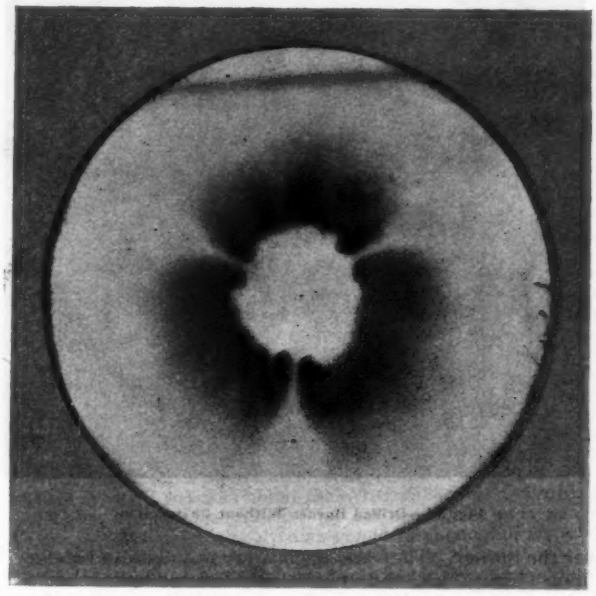


Fig. 5A.—Disc Burner.

Bunsen flame with a well-marked inner cone, it will develop a uniform circular scorch. If a second trial is made with another sheet held only an inch or so above the tip of the burner, the pattern will exhibit a clean-cut circular white

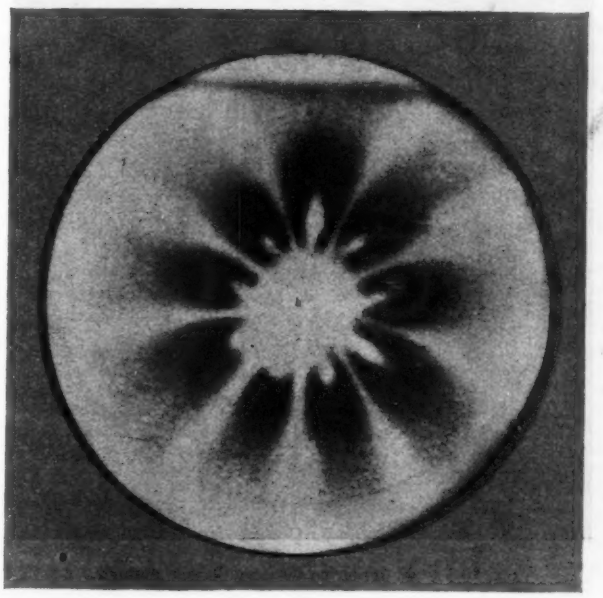


Fig. 5B.—Multi-Jet Burner.

patch in the centre of the scorch mark. This is a well known lecture experiment for demonstrating that the space inside the inner cone is quite cool and is filled with unburned air-gas mixture.

In Germany this experiment has been applied in an in-

teresting way to the examination of domestic ring burners and cooker burners. The burner is lighted and adjusted as for ordinary use; a circular piece of wood is then quickly placed on the pan-supports, where it is allowed to remain for some seconds; it is then quickly removed and the pattern burned on its surface is carefully studied.

The pieces of wood represent the base of a pan placed

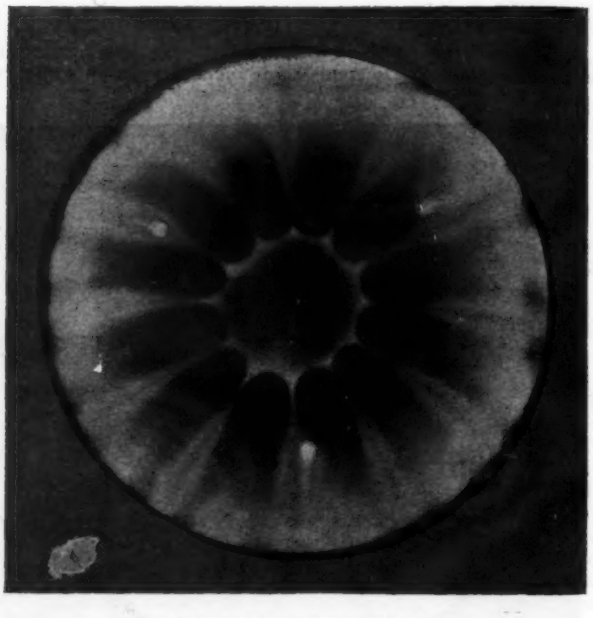


Fig. 5C.—Drilled Burner Without Obstruction.

over the burner. They are 25 cms. (10 in.) dia., and about 6 mm. (¼ in.) thick, and may be either single boards or be made of plywood. We have found that "Beaver Board" is even more suitable, being easy to work, flat, and of a uniform texture. The intensity of the scorching and the character of detail in the pattern are much influenced by the duration of exposure to the flame, and personal judg-

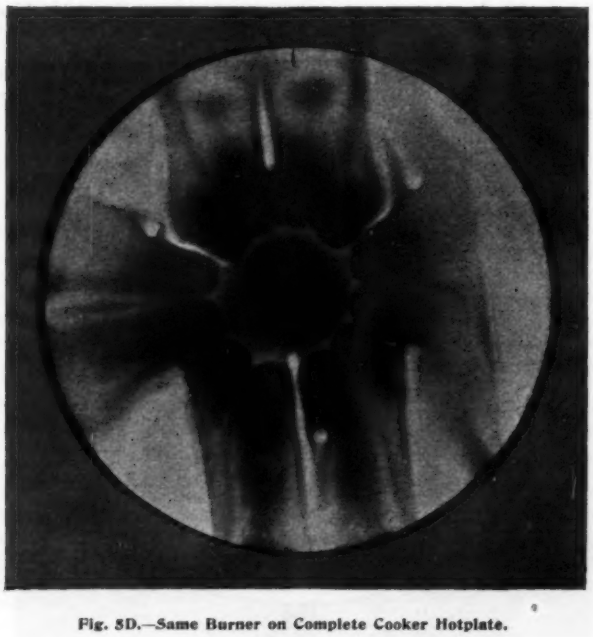


Fig. 5D.—Same Burner on Complete Cooker Hotplate.

ment here plays an important part. Several diagrams with different exposures may be necessary from the same burner, but an exposure of 15 seconds is useful for a preliminary trial.

Reproductions of four typical pyrographs are given in Fig. 5, A—D, all obtained with a gas-rate of 16 c.ft. per hour and 470 B.Th.U. gas.

What information can these pyrographic diagrams yield?

A well designed and properly constructed burner should yield a symmetrical diagram with each portion of the flame giving a clean, well-marked scorch.

If the pan-distance is incorrect and the inner cones of the flames are intercepted, there will be clear patches inside the scorch areas, as shown in Fig. 5 B.

Neither lack of symmetry nor the appearance of these clear patches is *proof* of imperfect combustion and the production of carbon monoxide, but they at once single out the burner as requiring further examination of its products of combustion by chemical tests.

Fuzziness in the outline of the scorches and feeble scorching may be evidence of smothering, but here, again, confirmation is required. The position of pan-bearers and the constraint they exercise upon the flow of the products of combustion is also indicated by such diagrams. It should not be forgotten that the scorch is made with the disc face downwards, but that it is afterwards inspected face upwards; the diagram is therefore reversed from side to side.

Fig. 5 C is a fairly good symmetrical diagram given by a recent drilled burner when the board was held with a special support offering the minimum hindrance to the flames. The adjacent diagram Fig. 5 D was obtained from the same burner when fitted to a certain cooker hotplate. The products of combustion are largely forced to pass to the front and back between the pan-grids, and there is little room for lateral escape, so that the base of the pan is not efficiently used for heat transmission, and some of the flames are certainly interfered with.

In the Tegel Laboratories of the Berliner Städtische Gaswerke, the preparation of these pyrographic diagrams forms part of the routine testing of gas cookers, and many such diagrams are filed in the Laboratory.

It will be realized that results obtained by this method cannot be expressed quantitatively, but they form a permanent record, and to an experienced worker convey information which cannot be obtained by visual inspection of the burner either with or without a pan in position. They are also useful for indicating to consumers and sales staffs some of the conditions under which combustion takes place. No appliance would be passed merely because its scorch diagram was satisfactory. On the other hand, a poor scorch diagram would indicate the desirability of going further with thermal efficiency tests and the chemical examination of the products of combustion from the burner.

DISCUSSION.

Mr. J. G. Clark (Gas Light and Coke Company): I should like, in the first place, to express appreciation of the work that Mr. Wood has carried out. I doubt if anybody who has not been engaged in this particular kind of work can understand fully how much patience, interest, and skill are necessary in carrying it out; indeed, it is doubtful if there is any branch of chemistry which calls for so much skill as does this problem of examining the phenomena of combustion in relation to gas appliances. The work is of the very first importance, and it seems to me that the Council and the Joint Research Committee were wise in putting this on their programme of research, and I hope they will be wise enough to keep it there for quite a long time yet, because the more work that is done in connection with the phenomena of combustion the more successful is likely to be the application of gas to cooking, heating, and lighting. I do not think we can ever regard things as being so good that they cannot be bettered, and, as combustion is the foundation of our business, the more work that is devoted to this subject the better.

Before I say anything about the details of Mr. Wood's work I should like to refer to the methods of expressing what I should like to term "combustion efficiency." When gas is burned, theoretically it should form carbon dioxide and water, together with a few other things which are of no great importance. A certain degree of incomplete combustion is inevitable. This takes the form of producing carbon monoxide, and the amount may be small or serious, according to the combustion conditions. I like to think of the ratio of, say, CO to CO_2 as representing the efficiency of combustion. Although, on a scientific basis, it is not likely that we could ever get to 100 p.ct. efficiency, we must get nearer and nearer to 100 p.ct. The figure representing combustion efficiency is expressed in a variety of ways. We sometimes speak of it as a CO : CO_2 ratio. Mr. Wood has expressed it sometimes as parts of CO per 10,000 c.ft. of gas burned, sometimes in terms of parts of CO per 1000 or 10,000

c.ft. of products, and so on. I think it would be well if we could arrive at some standard basis on which all of us working on these lines could express our results, so that we could all understand each other.

Cluster Lamps.

In regard to lighting, Mr. Wood's results are extremely interesting, and some are quite gratifying. It is interesting to note that the use of a globe improves combustion. We recommended the use of diffusing glassware with mantles in order to improve the light and obtain better diffusion; if it improves the combustion also, well and good. It is all in the right direction. Looking at the figures from the point of view of the efficiency of combustion, it would appear that combustion is not so good always as we should like it, and therein is room for improvement. Nevertheless, we must maintain a sense of proportion in these matters, because, after all, a gas burner burns so little gas that even what we might call a high proportion of CO might be a negligible quantity when considered in relation to the ventilation of the room in which the gas is burned. Thus, we must maintain a sense of proportion in interpreting these results. Mr. Wood alluded to some interesting facts relating to the character of the flame and the light produced. I think he mentioned that, at a lower aeration, a better light was produced. Of course, as we all know, the light we get from a mantle is a compound of quite a number of things. There is the temperature of the flame, the shape and size of the flame, and the mantle itself. We may have the very best flame in the world, but if it is burning inside the mantle, and not in contact with it, we get practically no light. All these things make it difficult to relate flame condition with light emission. I should like to say, in this connection, that it is probably fairly well known that there is an important relationship between the flame and the mantle, and it appears more particularly in connection with cluster lamps. We have a means of using a cluster of mantles fed from one burner—one injector, one mixing chamber, and a series of nozzles at the end. With such a burner we cannot adjust any one of the flames to fit any one mantle; they must all be adjusted together as a complete unit, so that if we have mantles varying considerably in size on one burner we may adjust the flame to suit one mantle, but not the others. So that we must have mantles of very nearly the same size. That matter is important, and if it has not received attention everywhere I advise that it should be considered. It is quite easy to obtain mantles of similar dimensions. We in the Gas Light and Coke Company specify certain minimum variations in the dimensions of mantles; unless we do this we do not get the best lighting effect from the cluster type of burner.

As to surface combustion, Mr. Wood's remarks rather confirm the views I have held myself. We have tested several of that type of appliance, and I made a strong recommendation to the makers that they should always use governors with their apparatus. It is quite a satisfactory, and a very efficient, way of consuming gas, but sometimes the variations in gas consumption may interfere very seriously with the combustion and the efficiency of the apparatus, and, inasmuch as that can be prevented by the use of a governor, there is no reason why that drawback should enter into the matter at all. If a governor is used, the combustion will be kept within the narrow limits required to ensure proper efficiency, and thereby the apparatus can serve a very useful purpose indeed.

Flueless Stoves.

In regard to flueless stoves, Mr. Wood has not done anything yet, apparently, but I have no doubt that work on such stoves is included in the programme and will be done in due course. We have examined quite a number of modern flueless appliances, and our view is that they are exceedingly good. The combustion efficiency is of a very high order, and, indeed, it could not be higher, as far as I can see, and personally I am very pleased with many of the flueless stoves available now. I should not like to have said this of the flueless stoves we had ten years ago, but I hope that when Mr. Wood comes to test the modern flueless stoves he will be as satisfied with them as we are. This reminds me of an interesting point on the chemical side. Mr. Wood has no doubt encountered the experimental difficulty of allowing for the CO in the air in which the stove is tested. The air may be already laden with a certain amount of CO, and this has to be allowed for in the final result. I cannot see any complete solution of the problem, other than taking care that there is so little carbon monoxide in the air of the room in which the test is made that it can be neglected altogether. It must always happen that some of the CO passing into the stove from the air must be consumed; and this is illustrated very simply in connection with these flueless stoves. The combustion is so good that you may have an ordinary atmosphere, such as you are commonly breathing, and containing so much CO that the air would be purified in passing through the flueless stove. This may sound incredible, but it is true. The air at places such as Vauxhall Cross, Victoria, the Bank of England, and so on, contains several times as much CO as there is in the columns of these flueless stoves, so that, if such air were passed through the stoves, it would undergo a considerable degree of purification.

In regard to the Vandaveer and Gregg apparatus, we are using it at Watson House, and, although admittedly it has limitations, we find it quite useful in expediting some of the work we have to do. Also, we find the Katz apparatus more and more useful. It is true, as Mr. Wood has said, that ordinarily it requires from 40 to 60 litres per minute to obtain a result, but we have modified it so that we can get down to 15 litres, and we find that this is sufficient to give us a good result. We hope to reduce that quantity still more, so that the apparatus will be more and more useful as a recorder of CO quantities.

Value of Convection.

I am very interested in Mr. Wood's allusion to the German Gas Exhibition. I had not the pleasure of visiting it, but there are two points in his remarks which are worthy of comment. First, there is the question of convection. He alluded to German stoves designed to provide convection in connection with room warming, and I think this is an opportune moment for the raising of this question of the value of convection. My own feeling is that very soon we as an industry will have to turn very sharply against our ideas that radiation is the only factor that matters, and we shall have to provide more convection. I am not unmindful of the history of this matter. I remember some of the stoves we had in use 20 or 25 years ago; they were certainly not things to be proud of, but they were efficient in the sense that they warmed a room—partly because they gave off quite a large amount of convection, and partly because not a small part of the products of combustion came into the room instead of going up the chimney. [Laughter.] It is easy now to look back and appreciate where we went wrong. If we had searched for the real defects of the stoves—imperfect canopies, dirty and defective chambers, and so on—we might still have had a certain amount of convection, which would have added to the heating power of the stoves. It is important to take note of this, and I hope that in the next few years we shall see more development in that direction, because I am sure we shall not be able to increase the use of gas fires in living rooms almost continuously until we have a substantial amount of convection added to the radiation emitted from the stoves.

Mr. Wood's remarks about the pyrographs were interesting; and they remind me of what we did some five years ago in London. We did not apply that wonderful name, but we made quite a lot of photographic representations of different types of burner. We used a steel plate of reasonable thickness, painted with a white paint which would discolour by temperature, and with this we were able to take photographs and study some of the effects produced. My idea was not to study combustion by that means, but rather to examine the different ways in which the heat was transmitted through a vessel placed over the burner. It was suspected at that time that the tendency of some of the burners we had was to burn the food inside a saucepan, owing to the concentration of heat on the vessel, and this pyrographic device was useful for measuring the concentration of the flame and the density of heat transmitted to the different parts of the plate.

Mr. Wood: I have to thank Mr. Clark for the kind remarks he has made about our work. I think the Institution ought to know that the Gas Light and Coke Company themselves are carrying out a very considerable amount of work on the examination of the products of combustion from gas appliances, and that through the kindness of Mr. Hardie and Mr. Lacey we have been able to see some of that work and have derived considerable help from mutual comparisons of results.

Methods of Expressing Results.

It would be out of place here to discuss the merits of the different methods of expressing results. The CO : CO_2 ratio is quite satisfactory in some ways, but the disadvantages are that the CO_2 production of the gas per c.ft. is itself liable to some variation, and the CO : CO_2 ratio does not give any idea of the actual output of CO. For that reason you will find two figures in our report—the output of CO per 10,000 c.ft. of gas burned, and the total output of CO, in c.ft. Those figures, taken in conjunction with room capacity or known ventilation, will enable you to say whether the possibilities of CO poisoning are likely to be serious or not.

We have examined one flueless heater, using an Argand burner. It was reported upon in the 17th Report, and, although the excess air flowing through the apparatus was very small, combustion was remarkably efficient. Mr. Clark's reference to the consideration of the CO in the air, when calculating results, is rather interesting. In quite a number of cases we have had negative results; I mean that the amount of CO in the products of combustion leaving an appliance has been less than that in the air which has been fed to the appliance. The CO is undoubtedly burned up in the flames of such burners, and it is extremely difficult to decide what to do in regard to this when calculating the results of tests. A principle which I think we must bear in mind is that, if the greater portion of the air supplied to the appliance passes through the flame zone, then we can neglect the CO in the air. It is simply included with the CO which is ordinarily present in the flow of the products of combustion, and we need not worry about it further. On the other hand, if we are dealing with an appliance which takes a

very considerable excess of air, of which a great deal goes nowhere near the flame, then we are justified in deducting from our CO figure in the products that amount which appears in the air supplied to it. In regard to the intermediate stages, I do not know what you could do. The only thing to do in the case of testing is to test in as pure an atmosphere as possible. The calculation of any correction is likely to be a very dangerous thing.

I think, with Mr. Clark, that the convector will come back into use in the industry considerably, though not to the exclusion of the radiant type of gas heater.

Mr. W. J. A. BUTTERFIELD: I had not intended to speak, but, as the President has called upon me, I will mention one matter. The suggestion Mr. Clark has made with regard to the expression of results—it had already occurred to me when I read the Report—is a most valuable one. We have to bear in mind that these research papers do go outside the immediate circle of the members of this Institution, and there is a serious risk that their contents may be misinterpreted. We have to bear in mind the partially informed popular journalist who may get hold of one of these reports. A little knowledge is a very dangerous thing. He sees in a report the proportion of CO stated in parts per 10,000 of gas burned. He has got the information from somewhere that one part of CO in 10,000 of air is a dangerous proportion, and that after so many hours it may cause death. Mixing the two facts, he has all the material for an explosive mixture—[laughter]—to which he will give play in the largest headlines his Editor will allow. I do suggest that, in future reports, an additional method of stating the results should be included. The method used is the right one for scientific purposes, but we should also give a lead to people who may not have all the knowledge necessary to enable them to follow these reports in the proper sense. I think that in these reports the CO : CO_2 ratio can easily be found, but we should go a stage further and assume that in any given room there is an accepted standard of ventilation, based on the proportion of CO_2. You take the factory daylight standard of 10 parts of CO_2 per 10,000, and you state, in regard to each appliance that is dealt with here, at its worst, what the proportion of CO would be in the air of a room when 10 parts of CO_2 per 10,000 are present in the room, derived from the gas appliance. Then you would show the proportion of CO which may occur in the air of the room in its real proportions, and any member of the public, when reading it, would not misunderstand.

I should like to add my testimony as to the excellence of the work recorded in this report, the immense amount of it, and the great care with which it has been done. The report contains material of a most valuable character for our guidance in the future.

Mr. WOOD: I should like to say that I am quite in agreement with Mr. Butterfield as to an alternative method of expressing results. In the report we have made notes in order to avoid duplication of figures. At the foot of our main tables, for example, there is a note to the effect that the amount of CO in the theoretical products of combustion, without any dilution whatsoever, is about a quarter of the figures that we have given per 10,000 on gas burned. The only objection I have to Mr. Butterfield's method of stating results—I believe this matter was raised in the course of the discussion on a previous report—is that the products of combustion are not, or may not be, uniformly diffused throughout the apartment, and we have to consider the case of a person who might be placed relatively close to an appliance and who might be subjected to greater concentration of the products of combustion than will prevail throughout the greater space of the room. With the general principle, however, that the results should be expressed in such a way as not to be misleading to the Press and the general public I am entirely in agreement.

WHAT IS A TYPICAL APPLIANCE?

Mr. JOHN WILSON (Motherwell): I suggest with a certain amount of diffidence that all the work which the Research Committees have done in connection with gas appliances has been in no small measure detracted from owing to the fact that the Institution—and I take it that the Institution is the governing body of the gas engineeers—has not so far seen fit to standardize various appliances. It is stated in the 25th Report of the Joint Research Committee what they have discovered in connection with typical gas appliances; but I question very much if they are typical. I question very much if we can say that any gas appliance to-day is typical. Take the gas burner. The gas burner of to-day can be anything at all. We pick up one gas burner, but this does not necessarily mean that it is typical of any other gas burner you could name; and I do think that before any further investigations are carried out in this direction the Institution should undertake an inquiry as to the best form of burner that can be used for a special purpose.

Mr. SHAPLEY: Do you think that, even if the Institution stipulated a particular kind of appliance, gas engineers generally would accept it?

Mr. WILSON: That would be their funeral.

Mr. SHAPLEY: The Institution has been faced with this on many occasions, and they have hesitated rather reluctantly to dictate in any way to gas engineers. It came before the Purifiers Sub-Committee, of which I happen to be Chairman. I was urged to lay down hard and fast rules for emptying purifiers, but the Council, in their wisdom, backed me up in saying they did not think engineers generally would appreciate any dictatorial instructions from the Institution Council. Probably that would be one of the difficulties to meet if we were to consider the standardization of gas appliances, because we must not forget—and I think everyone present will pay testimony to the gas apparatus manufacturers—the advances which have been made by the manufacturers, which have helped us very materially. True, we have helped them to solve certain difficulties in working out new apparatus; I will not mention any particula. apparatus, but I have found out certain difficulties with regard to new apparatus made by the gas appliance makers, and we have co-operated together and pooled our brains and improved the apparatus. But I do not know whether the general body of members would appreciate the Institution saying *this* is the standard cooker or *that* is the standard burner. That is one of the difficulties the Council is up against. We are only a Council of 26 representing 1400 members, and we have to move a little guardedly.

Mr. WILSON: I quite agree, but the Council have accepted this report as having investigated a typical gas burner; and I say "Is it?"

Mr. SHAPLEY: Mr. Wood was operating at our Meadow Lane Works, and I can say that all the apparatus he used and tested was of the highest order.

Prof. COBB: I should like to confirm what Mr. Shapley has said. Anybody who knows Mr. Wood and the conscientiousness with which he follows up his tests will also appreciate that he shows the same conscientiousness and is equally careful in making his decision as to which appliance his tests are to be carried out on, and in making perfectly certain to his own satisfaction, and that of the Committee to which he reports in the first instance, that all the appliances which he uses can be accurately described as typical. It was the deliberate policy of the Committee not to publish the actual name in connection with any burner or appliance, if it could possibly be avoided; and therefore that was not done. But I think that if the name in each case had been published it would probably have been seen at once that there was no doubt at all about Mr. Wood being perfectly right in taking it as typical, and of the correctness of the action of the Committee in endorsing his view, because that also comes in.

The PRESIDENT: With regard to the standardization of appliances, as a broad principle I do not mind saying that I am rather opposed to standardization, because it tends to create a state of stagnation, and prevents evolution. Nearly all our successes have been due to one man trying to outdo the other; and this is a very healthy state of competition. But it would be very dangerous for any Committee to take any particular article or appliance and say "That is the thing we consider typical, and that is the thing we consider best." You would have all the other manufacturers saying they were being done an injustice, and quite properly. To illustrate my point, only a day or two ago the Council of the Institution appointed a new Committee which is to investigate all the lighting appliances that are at present in use for the lighting of streets; and this Committee is going to confer with the manufacturers. The Committee has the power to co-opt additional members, and it will approach anybody whom it is thought can help in improving appliances, wherever available, for public lighting at the present moment. I think this illustrates my point that the Institution has not been so lacking in activity as some people might think.

21st Report of the Refractory Materials Joint Sub-Committee

The members of the Refractory Materials Joint Sub-Committee for 1929-30 were: J. Ferguson Bell, Prof. J. W. Cobb, Dr. H. G. Colman, R. E. Gibson, T. Hardie, H. D. Madden, W. E. Price, T. F. E. Rhead, Dr. E. W. Smith, F. P. Tarratt, and J. Wilkinson, representing the Institution of Gas Engineers, and T. Allen, M. Barrett, F. H. Brooke, G. V. Evers, J. W. Fagan, W. J. Gardner, W. T. Gardner, W. L. Jackson, G. H. Pearson Perry, Col. A. Stein, C. R. F. Threlfall, and Frank West, representing the Society of British Gas Industries, and Dr. J. W. Mellor, the Director of the British Refractories Research Association.

Having recorded the death of Mr. J. P. Leather, who was Chairman of the Committee since 1924, and the fact that Dr. H. G. Colman has been elected Chairman in his place, the report explains that the Institution of Gas Engineers, as a member of the Association, contributes a sum of £250 per annum to the British Refractories Research Association, and nominates two members of the Council of that Association, the present representatives being the Chairman of the Joint Sub-Committee and Mr. W. E. Price.

The total funds available for research to the Council of the Association have, however, throughout been insufficient to enable them to employ as many research workers as was desirable in view of the number of problems awaiting investigation, or to defray the cost of the necessary apparatus, which in many cases, owing to the nature of the problem, is expensive. The Sub-Committee is, however, glad to be able to report that there has this year been some increase in the funds available, chiefly due to a sum contributed by the iron and steel industry.

A commencement has now been made with a study of the problem of permeability of refractory materials.

REFRACTORY MATERIALS: RECENT INVESTIGATIONS.

1. *The Influence of Atmosphere on the Load-Bearing Capacities of Firebricks. H. T. S. Swallow, Bull. No. 21, B.R.R.A., pp. 23-37.*

In previous investigations (Vickers, Bulls. No. 8, 9, 11, and 16) it was shown that the ordinary refractoriness of cones made from artificial mixtures of seger cone materials with iron oxide—added in various forms and amounts—was lowered when the test was carried out in reducing gases such as hydrogen, methane, carbon monoxide, and steam instead of the normal oxidizing atmosphere. The extent of this lowering was proportional to the iron content of the mixtures. The results of other work on commercial firebricks of varying "iron" contents (Swallow, Bull. No. 20) gave no definite indications of the generality of the results quoted above. With the object of obtaining more definite knowledge, tests on the refractoriness-under-load, in different atmospheres, of firebricks containing various amounts of iron oxide, have been completed. The following notes contain the main results of the work.

The atmosphere of the load test furnace was found to be normally oxidizing. It is suggested that the influence of a reducing atmosphere on the behaviour of firebricks in use in high-temperature furnaces is apparent more in an increase in the amount of contraction than in a reduction of refractoriness or load-bearing capacity. Thus in one series of tests in which the temperature was held at approximately 1200° C. for some hours and the load was 50 lbs. per sq. inch it was found that practically all this contraction took place during the first three hours, and that very little contraction occurred during the last hour. Under a load of 50 lbs. per sq. inch, at 1200° C., the influence of a reducing atmosphere was to bring about a contraction of 3·4 per cent., as compared with 0·34 per cent. in an ordinary oxidizing atmosphere. It is further suggested that the change in the viscosity and the amount of the fluid portions of a firebrick at high temperatures due to the effect of oxidizing or reducing conditions on iron compounds can be arrested or even reversed by the application of the opposite atmosphere. At the temperatures at which these experiments were made—*i.e.*, 1200° to 1280° C.—the action of steam appears to be negligible compared with that of a strongly reducing atmosphere.

2. *Effect of Repeated Burning on the Structure and Properties of Lime-Bonded Silica Bricks. W. Hugill and W. J. Rees, Bull. No. 21, pp. 4-10, (a) Part II. The Determination of the Properties of Quartz, Cristobalite and Tridymite.*

Details of a revised microscopic method for the quantitative determination of the constituents of silica bricks are given. The relative proportions of cristobalite and tridymite were obtained, firstly, by immersing the finely-powdered brick in a liquid of density 2·5 and separating the portion which floated after standing for 24 hours. The quartz-free portion was washed, dried, and its density measured, the proportion of tridymite (density 2·28) and cristobalite (density 2·33) being then calculated. A diagrammatic representation of the results are given. It is shown that there is a rapid fall in the proportion of unchanged quartz up to the third burning, and that in subsequent burnings, the rate of inversion is much lower. The tridymite content increases and the cristobalite decreases rapidly between the third and the sixth burnings, but this change also slows down in subsequent burnings. It can, further, be seen that after eleven burnings, there is still 7·9 per cent. by volume, or 9·1 per cent. by weight, of quartz in the bricks. By extrapolation, it is deduced that these bricks would have to receive at least 20 normal burnings to invert the whole of the quartz.

(*b*) *Part III. The Determination of the Reversible Thermal Expansion.*

The method of Houldsworth and Cobb (Trans. Cer. Soc., 21, 227, 1921) was used. The α-β quartz change at 575°, whilst quite noticeable in material which has received only one burning, becomes very small in products of three or more burnings. Percentage linear expansion data is given as follows:—

—	15°–240° C.	15°–1000° C.
One burning	0·73	1·152
Three burnings	0·74	1·130
Six ,,	0·75	1·104
Twelve ,,	0·49	0·840

3. *The Effect of Iron Oxide and a Reducing Agent on the Rate of Inversion of Quartz. W. J. Rees and W. Hugill, Bull. No. 21, pp. 17-19.*

Four batches of silica brick, using Sheffield ganister as the basic raw material, have been made. Batch No. 1 contained 1·68 per cent. of lime, No. 2, 1·68 per cent. of lime and 1·5 per cent. of finely-powdered carbon, No. 3, 1·68 per cent. of lime, 2·5 per cent. of iron oxide added as a finely-ground mill scale, and 1·5 per cent. of powdered charcoal, No. 4, 1·68 per cent. of lime, and ferrous oxalate to give 2·5 per cent. iron oxide. The bricks made from the batches containing iron oxide and a reducing agent have a decidedly lower total thermal expansion in the range 15° to 1000° than the normal lime-bonded brick. The addition of carbon alone has a very slight effect in reducing the

thermal expansion, probably due to its action on the iron oxide present in the original ganister.

4. *Note on the Effect of Iron Oxide on the Rate of Quartz Inversion. W. J. Rees, Bull. No. 21, pp. 20-22.*

Results which form interesting confirmation of the influence of iron oxide in promoting the crystallization of tridymite are given.

5 *The Corrosion of Refractories by Glassy Slags. Part I., with Appendix. A New Method of Investigation, the Apparatus, and Preliminary Results. A. J. Dale, Bull. 22, pp. 48-68.*

A novel apparatus for examining the resistance of refractory material to corrosion by molten glasses, &c., which has now been designed, constructed, and calibrated, is described. This apparatus automatically provides a record of the change in apparent weight of a refractory wholly or partly immersed in a molten glass or slag.

In some preliminary work the apparatus has been used to investigate the penetrability of refractory materials by water. An analysis of the data so obtained enables some conclusions respecting the size and number of the pore-spaces, skin effects, &c., to be drawn. The following form the chief indications of this portion of the work :—

(1) There is no direct relationship between the initial rate of absorption and the apparent porosity for refractories of medium porosity (20 to 25 per cent.).

(2) Abnormally low porosity is accompanied by very low absorption rate; whilst extremely high porosity is associated with very rapid absorption.

(3) With some refractories skin resistance to penetration by liquids is very marked and removal of this skin greatly increases the initial rate of absorption.

(4) Generally speaking, four types of porosity have been roughly identified.

It was noted, in all cases, that during an actual test water appeared at the upper brick surface long before absorption was complete. This, of course, is attributed to the rapid filling of the straight or largest pores and the subsequent more gradual penetration of the liquid into the more erratic pores of smaller radii.

These investigations are being continued.

6. The following report has also appeared :—

Lime-Bonded and Clay-Bonded Silica Bricks Made from Calcined Ganister. W. J. Rees and W. Hugill, Bull. No. 21, pp. 11-16.

OBSERVATIONS ON THE BEHAVIOUR OF REFRACTORY MATERIALS IN CONTINUOUS VERTICAL RETORTS.

By A. T. Green, F.Inst.P., A.I.C.

General Considerations.

In the vertical retort both the surface temperature and the condition of the coking face of the retort are influenced by the charge in differing ways at different zones. For instance, the major deposition of scurf is normally encountered in the higher portions, whilst the principal slagging troubles on the coking side show themselves at the lower zones of the retort. The study of zonal effects is of the greatest importance in determining the factors influencing the durability of the refractory materials.

The systematic study of the condition of retorts after their effective life forms a source of valuable data. In this work information concerning (1) the internal dimensions of the retort at all levels; (2) the condition of the retort brickwork at all levels—based on a " brick to brick " examination; (3) the condition of the combustion chambers; (4) any other peculiar features, should be obtained. Sample of the materials from the various zones should be taken and subjected to laboratory examination, When studying this information it is essential to keep in mind (1) the history of the working of the setting; (2) the limitations in the properties of refractory materials under general carbonizing conditions; (3) the individuality of the carbonizing system; (4) the probable local peculiarities in operations; (5) the nature and influence of the coal used. The result of the work should be an attempt to assess the chief factors causing decreased durability. The records which must form a very serviceable basis of reference and indicate principles for the improvement of the existing practice, should then be carefully filed. This systematic procedure appears to be the only one capable of explaining the general and the particular features governing the life of a setting. It will certainly result in opinions which are not in keeping with the bald statement that " the refractory materials were at fault."

It is a well-recognized fact that there has been an upward trend in carbonizing temperatures. Consequently materials, which gave effective service under the old régime are often quite unsatisfactory for modern duties. Thus, silica products mainly because of their greater structural stability at elevated temperatures, are finding increasing use in the present-day gas retort, particularly for those zones where the higher heats persist. This introduction of silica materials is a comparatively modern innovation, and, therefore quite a number of features concerning the use and durability of these products are at present either not appreciated or imperfectly understood. In general, then, the argument of this paper centres round the behaviour of silica and siliceous products in the vertical retorts. The object of the paper is, primarily, to indicate the nature of the phenomena influencing the durability of refractories in vertical retorts.

Initial Heating of the Retort Setting.

The initial heating of a setting must be conducted with extreme caution until a temperature of 650° or 700° C. is reached. With the siliceous product there is less liability to damage by spalling owing to the lower cristobalite content.

The practice adopted for the initial heating naturally depends on the size and the design of the carbonizing unit. Usually, as a start, low fires are kindled in the producers and the warm gases are allowed to pass through the flues and combustion chambers of the setting. By means of these fires temperatures up to 400° C. or so in the flues and combustion chambers can be built up. It is apparent, then, that this method, which is capable of fair control by means of a robust thermometer or a base-metal thermocouple placed at the base of the producer-gas flue, will adequately dry out the setting and will overcome the difficulties of the low-temperature changes satisfactorily. A slow rate of rise of temperature is necessary in order to soak the setting. When the fires cease to produce the required rate of rise of temperature, it is necessary to proceed with gaseous firing. At the start of this procedure the temperature rises quickly, so that, generally, the quartz transition temperature is passed rapidly. Although the expansion associated with this change is not comparable with the cristobalite expansion, it is quite appreciable. Consequently, if the refractory material of construction contains quartz in any quantity, the very careful control of the first stages of gaseous firing is essential.

In the actual heating of a setting, as much as 15 to 18 days may be required to reach 120° C., and thus to drive off the water. This preliminary work of the heating operation is of some importance, since the too rapid production of steam from the water in the cement can result in the formation of cracks in these joints by the steam produced, which are thus predisposed to trouble. To reach 400° may take 25 to 30 days. A " straight " silica setting expands as much as 0·8 per cent. linearly, *i.e.*, about 65 per cent. of its total expansion, or 2 to 2·5 in. vertically when this temperature has been reached. A siliceous product expands about 0·2 per cent., *i.e.*, 25 per cent. of its total expansion, or about 0·6 in. vertically for the same temperature increase. With gaseous firing it is difficult to keep the temperature down, with the result that the full period of initial heating to the carbonization temperature may take between 32 and 36 days.

It is a matter of some experience to decide the amount and position of the expansion spaces. The modified refractoriness-under-load test with loads between 4 and 10 lbs. per sq. inch on the materials of construction gives very helpful expansion data. For instance, by means of this test, a " straight " silica brick shows an expansion of 1·1 to 1·3 per cent. when the temperature is raised to 1300°. This corresponds to an expansion of about 3 to 3·5 in. on a retort of about 23 ft. in height. Expansion spaces should be left as such. The practice of using a combustible filling material is to be discouraged for the obvious reason that this material does not burn out until the major ex-

pansions have taken place. Thus, the strains on the structure, which it was intended to relieve, can cause irreparable damage to the setting.

In the case of a "straight" silica product a material containing a very high percentage of tridymite is the most desirable, since the tendency to spalling at low-temperatures is comparatively small and the "growth" of the material in practice is negligible. Unfortunately, such a material is difficult to obtain commercially, silica products usually containing a high percentage of cristobalite. Nevertheless, the specific gravity of a "straight" silica brick for carbonization duties should not exceed 2·36. With siliceous products, these considerations are not so important, since under conditions of industrial usage this material does not tend to grow to the same extent, but matures to a hard, vitrified material.

The cooling of retorts, which are to be put in operation again, should be conducted with care.

Examination of Retorts: The Internal Contour of the Retort After Operation.

As already mentioned, it is definitely advisable to conduct an examination of a retort setting which has been shut down either for repairs or for reconstruction. Each retort should be examined and the position in the setting of the most affected retorts noted. This is important, since trouble often associates itself in particular retorts in each bed of the setting. Thus, the retorts near the producer may have been subjected to much more deleterious influences than those away from the producer. The reason for this may be connected with the increased throughput of the retorts on the producer side, with their higher temperatures of working, or some other factor which is incidental to the position of the retort in the bed. After a general examination of the setting, particular retorts which are to be dismantled should be further investigated in greater detail for the condition of the brickwork, the internal contour being measured at the same time.

With certain types of retorts it is advisable to measure the minor axis at all zones from the top to the bottom, taking a number of readings of the major axis at various positions.

On plotting the data, together with the curve of the original alignment, various features of importance may be indicated. Variation from the original alignment may be the result of a number of causes. In the first place, the coking of the coal in its early stages may exert considerable pressure on the walls of the retort in the upper zones, and tend to "bulge" these walls. This effect depends in some considerable measure on the nature of the coal; for instance, certain retorts using Durham coals of high coking value show it to a pronounced degree. Probably the careful selection and grading of the coals would tend to overcome the trouble, but this is not always an economical proposition. The flaking of the retorts about 10 to 12 ft. or so from the top of the retort may cause an increase in the "minor axis" measurement, whilst depending on the nature of the slag and its effect on the brickwork, the lower zones of the retort may show either an increase or a decrease in this measurement. If erosion "thins" the refractory the minor axis will be increased, if the slag adheres to the wall a decrease will result. Both features may be very harmful to the successful working and continued life of the retort. Again, expansion effects will be indicated, and these data may point to future alterations of design to suit local or other particular conditions. The visual examination of the retort brickwork indicates (1) the amount of flaking and spalling; (2) the nature and amount of slag attack; (3) the behaviour of the cement in the joints; (4) the probable causes of any observed "holing," including failure of the cement joint followed by the spalling of the corners in the early stages of the working. It may here be emphasized that practically every case of "holing" investigated by the present author has had its origin in the interior of the retort and *not* in the combustion chamber.

The Influence of Slags and Slag-Forming Substances on the Coking Surface, &c., of the Retort.

Foreign substances, such as iron compounds and alkali, pass from the coal and find their way to the surface and, also, into the pores of the refractory wall. Depending on the temperature and the atmosphere within the retort, such substances exert either a superficial disintegrating action or a corrosive influence.

Owing to the prevailing higher temperatures and the more acute reducing conditions, these features of retort troubles, including holing, are usually encountered in the lower half of the retort.

The precise slagging effect of the inorganic substances from the charge depends on the temperature and atmosphere in the retort. The conditions in the bottom zones of a retort are in keeping with an accentuated slag attack. The temperature is above that required for the formation of a viscous silicate, whilst the reducing atmosphere helps the "iron" to maintain the "ferrous" condition, a very important factor in slag formation. The temperature at these bottom zones being comparatively high, the fluidity of the slag is increased with consequent increase in its solvent activity. Because of the higher temperatures on the flue side the slag tends to be drawn through the pores of a silica retort, at the lower zones, thus augmenting its deleterious influence.

The viscosity or "stickiness" of the slag at the surface is very important in its influence on the passage of the charge through the retort. In fact, it is often surprising that so little slag accretion should be so harmful in this respect.

Four settings of retorts in different parts of the country, working on Durham coals, were investigated prior to and during dismantling. At gas-works 1 and 2, samples from the lower zones were taken from an individual retort in each setting. At gas-works 3 and 4, samples were taken from the lower zones of two retorts in the same bed. One of these retorts—in each of these beds—had received a conspicuous amount of slag attack, and erosion had taken place to some degree; the other was only superficially attacked. Sections through the materials and parallel to the coking face were cut and subjected to chemical analysis; in certain instances, an attempt being made to determine the ferrous iron. Table 2 gives the results.

The main features of this table may be tabulated as follows:—

(1) The penetration of the slagging constituents in the samples A, B, C, and E, and the superficial effects on D and F are exemplified by the analysis.

(2) In three out of the last four instances, the coking face chippings show an excess of "ferric" iron. This may be the result of oxidizing effects during the initial period of cooling down of the retort, when the superficial slag is in a fluid condition.

(3) The concentration of "ferrous" iron is very definite, particularly in the layers just behind the coking face; whilst the concentration of lime and alumina in these layers—an increase of 2 to 4 per cent. on the original material—suggests the penetration of the slag by way of the matrix of the brick.

(4) The incrustation on the flue side probably results from the action of dusts in the producer gases.

Temperature of working plays a big part in the passage of slags through the retort wall. Retorts C and D were in the same setting, C having been worked at a higher temperature than B. Similarly E and F were in the same setting, and in operation the same number of days, E having worked at a higher temperature than F. In the cases of C and E the slag has passed through the brickwork, whilst with D and F it has merely formed a superficial glaze. Experience suggests that a comparatively small increase in the flue temperature increases the slag passage very considerably.

In the case of silica and highly siliceous products, it has been noted that under some conditions the absorption of slag or dust rich in "iron" at high temperatures affects the softening point under load only to a relatively small degree. For instance, Sieurin states that the presence of "iron," estimated at 10 per cent. ferric oxide has only a very small effect on the under-load value. Iron compounds impregnating a silica product may have attacked or combined with the matrix, but the interlacing skeleton of silica mainly in the form of tridymite or cristobalite may be unaffected. Once this skeleton is broken down by solution rapid collapse of the material ensues. An under-load test on a siliceous product (92 per cent. SiO_2) impregnated with ferruginous matter and containing an average of

TABLE 2.

Description of Material.	Analysis.				
	SiO_2.	CaO.	Al_2O_3.	Fe_2O_3.	FeO.
GAS-WORKS NO. 1.					
Original refractory of construction (average analysis)	95·20	1·85	1·72	0·32*	..
Retort A. Badly affected material:					
(1) Chippings from the coking face	85·62	1·43	1·65	10 56*	..
(2) Layer 3–4 cms. thick, following (1)	82·21	2·93	2·72	12·62*	..
(3) End layer, flue side, with incrustation	92 10	1·72	1·93	4·43*	..
GAS-WORKS No. 2.					
Original refractory of construction (average analysis)	94·63	1·63	2·30	0·25*	..
Retort B. Badly affected material:					
(1) Chippings from the coking face	82·79	1 33	2·45	9·37*	..
(2) Layer 3–4 cms. thick, following (1)	78·35	2·72	4 63	11·79*	..
(3) End layer, flue side, with incrustation	92·10	1·51	2·53	3·64*	..
GAS-WORKS No. 3.					
Original refractory of construction (average analysis)	90·54	..	7·67	0·75	..
Retort C. Badly affected material:					
(1) Chippings from the coking face	81 28	..	7·95	4·85	4·07
(2) Layer 3 cms. thick, following (1)	76·54	..	9·40	1·31	12·50
(3) The following 2 cms.	80·02	..	11·33	0·95	6·12
(4) Next layer 3 cms.	84·18	..	9·73	0·92	4·21
(5) End layer, flue side, with incrustation	83·59	..	5·21	3·30	4·14
Retort D. Superficially slagged material:					
(1) Chippings from the coking face	69·41	..	4·29	19·21	3·52
(2) Layer 2 cms. thick, following (1)	90·62	..	7·52	1·02	..
(3) Flue side material	90·18	..	7·35	1·25	..
GAS-WORKS No. 4.					
Original refractory of construction (as for Gas-works No. 3)					
Retort E. Badly affected material:					
(1) Chippings from the coking face	77·46	..	8·64	2·08	9·27
(2) Layer 3 cms. thick, following (1)	82·06	..	10·57	1·26	5·78
(3) Next layer	84·26	..	11·97	0·87	3·98
(4) End layer, flue side, with incrustation	85·62	..	4·99	4·08	3 62
Retort F. Superficially slagged material:					
(1) Chippings from the coking face	78·28	..	3·78	9·30	2·17
(2) Layer 3 cms. thick, following (1)	90·40	..	8·94	0·62	..
(3) Next layer	90·87	..	8·11	0·65	..
(4) End layer, flue side, with incrustation	86·52	..	7·68	1·88	..

* The total "iron" was determined as Fe_2O_3. No estimation of ferrous "iron" was made.

8 per cent. of iron oxide (estimated as Fe_2O_3) indicated the squeezing out of a very fusible iron slag in the neighbourhood of 1050°, but the test piece maintained its identity at a comparatively very high temperature.

The "holing" of retorts may be due either to the influence of slag followed by erosion or to a gas leak through an opened joint. It is fairly easy to distinguish the origin. The evidence of erosion can be readily detected, often visually, generally by measurement. An opened joint may be the result of the elimination of cement which is often followed by spalling of the corners of the refractory section. If a retort has been well matured—having been in operation for (say) 500 days—the surface of the lower half is adequately glazed with slag and the structure is monolithic. In these circumstances holing by reason of gas leaks is unlikely.

Summing up, it appears that slag actions will take place in all vertical retorts, the extent being dependent on (1) the nature of the inorganic constituents of the coal; (2) the design of the retort; (3) the manipulation of the retorts, particularly with respect to the temperature of working and the extent of steaming. The influence of the slagging action may be very injurious in causing (1) erosion, that is, the rubbing away of the slagged surface by the charge; (2) failure of the brickwork through acute slag penetration; (3) "sticking" of the charge. All three types of trouble are often encountered in retort working. The ability of the siliceous and the silica products to absorb ferruginous slag is a good property, for it tends to prevent slag accumulation on the surface, which would seriously alter the lines of the retort and influence the passage of the charge.

FLAKING AND SPALLING.

In the zone of a vertical retort roughly from 6 ft. to 12 ft. from the top portions of the refractory surface are often dislodged. This material is apparently caused to peel off in thin flakes, sometimes mere films of material, often adhering to carbonaceous scurf. An examination of a cold operated retort generally shows that at the zone mentioned the coking surface is of a soft, friable, "mushy" nature, and that portions can be dislodged in considerable quantities by tapping the wall with a pencil.

The following is an interesting study of two flaked portions of a retort made of silica firebrick. Piece A was on an average 0·6 in. thick, the flaking rupture having taken place parallel to the coking surface. Indications of the influence of considerable heat work on this specimen were given by (1) the general closeness of the texture, and (2) the presence of parallel cracks running into the "flake." Piece C, 0·5 in. in average thickness, showed similar features. The outside of each piece—*i.e.*, the face which had been in contact with the charge—showed only a very slight superficial action of slag-forming constituents. The inside—*i.e.*, the plane of rupture—was coloured a brownish-red, probably by iron compounds, which had passed in the gaseous form to a preliminary crack, before actual breaking away took place. Small pieces were taken from the outside and the inside to a depth of $\frac{1}{16}$ in. to $\frac{1}{8}$ in. and analysed. Further representative portions of each fragment were used as the basis of true specific gravity determinations. The results are shown in Table 3.

TABLE 3.

Determination.	Fragment A.		Fragment C.		Normal Unused Material.
	Outside.	Inside.	Outside	Inside.	
Iron oxide	0 59	0·62	0·65	0·64	0·3–0·7
Alkalis $\{K_2O / Na_2O\}$	2·40	1·74	1·85	1·53	0·4–0·9
True specific gravity	2·47		2·51		2·56

Again "flakes," taken from four "straight" silica retorts, showed an average specific gravity of 2·32, and an average alkali content of 0·73. The average specific gravity of the original silica product was 2·36 and the average alkali content 0·52 per cent.

The results indicate that the usage of the retort has resulted in (1) a very slight increase in the amount of "iron;" (2) an increase in the alkali content; (3) a considerable decrease in the true specific gravity of the refractory. The increase in the alkali content is perhaps sufficient to cause a somewhat greater tendency towards vitrification at high temperatures. Further, such impregnations may be the initial cause of localized strains, a point worthy of consideration, but it would appear that in the present investigation, this influence was of a supplementary nature.

The specific gravity of the flake has suffered a considerable decrease during usage. This decrease is normally brought about by a considerable increase in the heat work at high temperatures—*i.e.*, over (say) 1250° C. A reduction in the specific gravity of a silica material is invariably associated with an expansion. Assuming, therefore, the existence of localized high-temperature fluctuations during the operation of the retort, it would appear that we have conditions which will result in a surface disintegration.

During the scurfing operation itself surface disintegration at the zone mentioned often takes place, pieces of the refractory coming off with the scurf. There can be little doubt that where scurf is burned off by the admission of air, localized high temperatures owing to the rapid combustion of the carbonaceous matter may result, following which there may be a fairly rapid cooling effect. The surface in contact with the scurf has probably been

weakened at definite planes by (*a*) depositions and impregnations; (*b*) constitutional changes in the silica in the surface layers resulting from previous high-temperature scurfings; (*c*) a general spalling tendency of a silica product. Thus, the influence of such periodic high temperatures, besides embrittling the surface, may easily disintegrate an already weakened material. The surface of the retort at the flaking zone is not equally affected. Those portions of the retorts adjoining tiles or which are otherwise supported do not show the trouble to the same degree as those which bound the combustion chamber. Again, certain retorts in the setting, by reason of their position, receive a lower and less variable flue temperature. These do not show the trouble to the same extent. These observations point to the fact that the combustion chamber temperature and its possible variability, although not necessarily the direct cause, have an influence on flaking.

The properties of the scurf itself have received little attention. There can be little doubt that the extent of the adhesion of this substance to the refractory, together with the amount of its thermal expansion or contraction during the operation of the retort, particularly scurfing, play some part in the disintegration of the refractory surface. Experience with different retorts carbonizing different coals suggests very strongly that the nature of the scurf varies considerably with the coal used and the carbonizing conditions, chiefly including temperature. For instance, the tenacity with which the scurf is held to the surface varies very much in different settings. It is also probable that the thermal volume changes of the scurf also vary with its nature. It would seem then that the phenomena associated with the formation and rate of growth of scurf require careful definition. Again, since the scurfing operation is a vital necessity for successful vertical retort work, investigations concerning the influences of this operation on the condition of the retort surface are required to be made. It is probable that some variation in the method of scurfing may reduce the flaking of the retorts.

Spalling can be regarded as the failure of a refractory to withstand without disrupture those stresses induced by temperature fluctuations or thermal shock. Flaking may thus be regarded as a particular type of spalling. Cases of spalling, however, are encountered which do not belong to the category of flaking. For instance, where the cement from a joint has been eliminated the corner of the silica block may be found to have spalled away. Here it is probable that fluctuations of temperature acting on a free corner of the material have caused the spalling. Again, as already mentioned earlier, rapid cooling of a setting can result in the formation of very wide cracks running down the retort from the top. These are instances of more or less " pure " spalling, which can be overcome by proper care. For instance, close-fitting sections requiring but little cement may prevent the liability to spalling at the corners. Again, the cooling of a retort, which is to be put into service again, must be conducted with almost as much care as the initial heating.

The alteration in the nature and constitution of the refractory by continued usage has an influence on the spalling tendency. Increased vitrification increase this tendency. Interpenetration of dusts and crystallizing substances into the pores, impregnations of slag-forming substances weaken the material. Consequently, in general, it may be asserted that continued usage influences the spalling tendency of the retort lining.

Many of the retort troubles are reported to start at the joints. It is easy to see that if the joint is thick and the cement weak, the latter can be forced out of the joint, and the corners of the refractory caused to spall. Leakage, followed by " holing," will probably result. In these circumstances, it is essential that the joints be as thin as possible. To obtain such joints (1) the refractory section must be true to shape, and (2) the cement must be uniformly finely-ground and plastic. To obtain and control the required texture of a cement is a comparatively easy matter. With silica cements, plasticity can be obtained either by (1) the presence of a naturally-associated clay, (2) the addition of an artificially admixed clay, or (3) the addition of a plasticizer of the nature of cellulose liquor, glue, etc. The presence of clay in excessive quantities results in a contractile cement, which may cause much damage to the retort, in the first place by influencing the positions of the retort sections with respect to each other, and, secondly, by tending to fuse into the refractory material. Again, an artificial plasticizer such as cellulose liquor burns out of the cement, without inducing any tendency to vitrification, probably leaving the cement in a somewhat " powdery " condition. The cement, owing to lack of strength, may thus be removed from the points in the very early life of the retort. Experience shows both these phenomena to occur. A cement should be of such a composition that it is capable of forming and maintaining the whole retort as a monolithic structure without showing contraction or interaction with the refractory of construction. To the author a controlled amount of clay (say, 7 to 10 per cent.) is no disadvantage.

The Conditioning of Hot and Cold Retorts.

In the first place, the composition of hot-patching mixtures has received little attention from the aspect of retort durability. Such compositions may contain very injurious ingredients. It is, of course, essential that the cement shall hold fast to the high-temperature surface immediately on application. To obtain such materials, substances which increase the vitrification properties of the mixture are often added. In fact, sodium silicate is a constituent of a number of proprietary cements, whilst ground glass finds its place in others. Depending on the zone to which these mixtures are applied and the amount of the fusible constituents, the cements may or may not be harmful to the retort. The influence of alkali concentration on the retort surface in causing slag formation and " stickiness " has already been indicated. Of course, much depends upon the temperature of working; where high temperatures are in vogue the use of cements containing appreciable quantities of fusible constituents is dangerous. With combustion chamber temperature under, say, 1230°, cements containing limited and controlled amounts of vitrifying substances may not be harmful. However, in one instance which came to the author's notice, 6 per cent. of red lead had been added to the cement. Thus, rigid examination of hot-patching cements is desirable.

Certain mixtures are suspended in water and sprayed on to the retort. The principle of the operation has little to commend it, since by the mode of application the retort surface must be subjected to a very sudden cooling. Spalling of the material can easily result. There is every reason why the top portions of the retort should not be sprayed, since more particularly the surface material is already in a weakened condition, consequent on those actions which produce flaking. Certain satisfactory results for the spraying of the bottom section already covered with a slag have been reported. The problem of hot-patching is very difficult of solution, and often it is a matter of an individual remedy for a particular retort.

All cold retorts should be reconditioned before restarting to work. Pointing and washing the surface with a silica cement—free from added fusible ingredients—are very valuable operations.

Conclusion.

The object of this paper has been to bring forward data showing the deleterious influences affecting the life of refractory materials in continuous vertical retorts. Starting with very high grade refractories and an adequate cement, there are actions consequent on the nature of carbonization which will ultimately cause the materials to fail. By proper care in the manipulation of the retorts, however, a profitable life should be obtained from a setting of high-grade material and adequate cement. There are many problems which, when solved, will lead the way to a material increase in efficiency. From the very nature of the difficulties, the method of " trial and error " seems to be the only one which will eventually prove successful.

One of these problems appears to the author to be concerned with the question of the selection of the refractory materials of construction. This paper has indicated the zonal nature of certain of the troubles. It is feasible, therefore, to suppose that different types of refractories are required for the different zones. Whilst it is not desired to convey the impression that many types are required, it is reasonable, for instance, to think that a special type could be developed to resist the flaking action better than a silica brick. The introduction of this new type over some four feet of the retort length might cut down flaking to a minimum and reduce the necessity for hot-patching of

the top zones. At the moment it appears that the possible refractories which could be used for high temperature carbonization and would resist flaking must be comparatively costly. If, however, such products increased the certainty of continued operation by 500 days, they would amply repay the extra cost. Similarly, the zonal nature of vertical retort working suggests that the constitution of a cement must vary with the zone of the retort. It is along these lines that progress with gas-works refractories is likely to be made.

Dr. H. G. COLMAN (Chairman of the Sub-Committee), prior to the introduction of the report, said: I want to refer to a matter I mentioned when I was re-appointed Chairman of the Committee after a lapse of ten years, and that is the loss which the Committee sustained as the result of the resignation of the late Mr. J. P. Leather, who rendered distinguished service to the Committee during his long period of Chairmanship. Not long after his resignation we received, with equal regret, a report that he had passed away, and I want to renew our expressions of regret at that sad event.

Mr. A. T. GREEN presented the report.

DISCUSSION.

Mr. FRANK WEST: The annual presentation by the Refractories Committee of new data on refractory materials is always awaited by us with keen interest, and particularly by myself, in view of my peculiar privilege of being able to look at these problems, from both the manufacturer's and the user's point of view. Each year, in my opinion, we are progressing steadily in the evolution of a sound technology for the production and use of refractories and this year the trend of investigations contained in the report increases our appreciation of the limitations of these materials. We must not forget that the British Refractories Research Association is dealing with fundamentals, as reported by the Chairman of the Joint Council; and although a great deal of work has been done in this respect in the past since its foundation, there are still many more problems to be surveyed, and patience must be observed during such times, as one cannot always report practical data for any particular industry every year, but this time there is some very interesting matter.

The report may be divided roughly into two sections:

(*a*) The study of the behaviour of refractories in vertical retorts by deductive methods.

(*b*) Efforts to elucidate the behaviour of refractories by simulative experiments.

The valuable contribution "Observation on the behaviour of Refractory Material on Continuous Vertical Retorts" will be greatly appreciated by both manufacturers and users of refractory materials, since it throws considerable light on the mechanism of the reactions which bring about different types of troubles at the various positions in the retorts. It also illustrates the widely varying conditions obtaining at different zones. The data presented and the discussion of the flaking and erosion problems are, in my opinion, worthy of the most careful consideration by all users, especially in view of the undoubted importance of the physical and chemical characteristics of the coal being carbonized. The suggestion regarding the use of different materials in different zones requires further investigation and serious thought given to the question of variation in physical and chemical characteristics of such materials. I strongly support Mr. Green's suggestions regarding the great care necessary in the heating-up and cooling down of settings. Due regard should be given to the peculiar expansile properties of the materials. This paper, I hope, will be the forerunner of much intensive work on these problems.

It is of great interest to know that work on cements and hot-patching materials is progressing, and it is hoped that from this work technical data will be forthcoming which will place the manufacturer and testing of cements on a sound comparative basis. As the question of permeability is intimately connected with the gas industry, it is gratifying to note that work on this problem has been commenced. Some quantitive definition of this feature is essential, at both low and high temperatures.

Studies by Mr. Swallow of the influence of atmospheres on the load-bearing capacity of firebricks provides interesting features from the carbonizing viewpoint. It is interesting to note that strongly reducing atmospheres bring about greatly increased contraction under load during the initial period of soaking at temperatures similar to those obtaining in retort settings, and that the effect of steam atmospheres in this direction is practically negligible. In view of the alleged abnormal effect of steam on the normal refractoriness of iron-bearing materials, this result is unexpected; and it is suggested that this work should be extended to include silica, siliceous, and super-refractories.

Messrs. Hugill and Rees illustrate by repeated burnings, the changes taking place in the expansile characteristics of silica bricks during usage. Their investigations on the effect of iron oxide and a reducing agent on the conversion of quartz has a direct bearing on the "spalling" phenomena observed in carbonizing practice.

Corrosion of refractory materials is a vital factor influencing the working life of retort settings, and researches which increase our knowledge of the mechanism of "slag penetration and solution" are exceedingly welcome. The preliminary indications of the work carried out by Mr. Dale suggest that this method of attack should be pushed forward with all speed since the information gained will materially assist in our search for economies in carbonizing practice.

Mr. C. M. D. BELTON (Shrewsbury): This is another extremely interesting report, and I regret that we have not had sufficient time to enable us to digest the contents of the reports thoroughly before the meeting. The reports were received only on Saturday morning, so that we have not the opportunity to devote to them the time necessary to enable us to consider them adequately. With regard to this report on refractories, it would appear, from Table 2, and the remarks made by Mr. Green, that his experience has been with retorts constructed throughout of the same material. He also suggests that investigations should be made regarding zonal construction. In the setting of which I have had experience, use has been made of different materials in the different zones; during the last few years I have given this matter very careful attention, and I seem to have arrived at a construction with which fairly good results can be obtained continuously. I am using a 95 p.ct. silica material for a depth of from 8 to 10 ft. in the intense combustion zone, a material of lower siliceous content for the lower section of the retort, and an aluminous material for the upper 4 or 5 ft. This form of construction has enabled me to avoid the very serious pitting which previously occurred at the top of the retort, and it has enabled me to attain high temperatures without damage in the combustion zone itself. I am rather surprised that no reference has been made to such work in this report. I am sorry I have not with me the figures showing the actual compositions of the materials I use, but I must plead the excuse of shortage of time.

FLAKING AND SPALLING.

Flaking and spalling give great trouble to operators of vertical retorts, and some of the trouble appears to be due to the variation in the composition of the jointing material used for cementing the blocks and bricks together. It seems to be essential that the composition should be constant; otherwise, there is unequal expansion and the ultimate disintegration of the bricks referred to by Mr. Green. Another matter to which we must give careful attention is the method of scurfing. Unless the scurfing is done carefully, particularly from the very first heating-up of the retorts, considerable areas will flake; but if proper care is taken in the regulation of the temperature, and if you are not in too great a hurry to get the scurff off, and do not send unregulated blasts of air or steam through the retorts, these deleterious effects may be minimized.

POOLING OF KNOWLEDGE.

The PRESIDENT: I would appeal for a greater pooling of our knowledge, for I am convinced that a great many observations have been made by various people, and that there is still a great deal of knowledge on this subject which is not generally available. I can confirm what Mr. Belton has said as to the importance of selecting different materials for different zones. I have done it with very considerable success; it is a question of selecting the most suitable material for each particular zone, having regard to the conditions to be met there. It is difficult to obtain records of spalling and flaking, of course, because you cannot get up into a retort in order to photograph it; but I would suggest that a very useful method of obtaining records would be to use plaster casts. We have found out quite a lot about the physical defects of various refractory materials by observing the nature of the spalling or flaking. I am convinced also—and I said so, I think, to this Institution on a previous occasion—that the question of refractories is very closely allied to the question of heat transference; it is the rate of heat transference, as much as the temperature, that tells. With regard to the question of finance, I know, of course, that these investigations into refractories require financing, and I think you will appreciate, from the number of reports we have, that a good many people require funds.

HOT-PATCHING.

Mr. C. S. SHAPLEY (Past-President): I agree with Mr. Belton that it would have been very much better if we had had more time to study these very important reports presented to us, and I hope the President will invite any who wish to make written contributions to the discussion at a later stage to do so, so that we may have the benefit of those contributions through the medium of the "Transactions." Probably such contributions could be submitted to Mr. Green for his reply, which also can be published.

It is apparent, from this report, that at the moment we have not got a recipe for a successful method of hot-patching. In the report we are told that, for re-conditioning cold retorts we should use a silica cement, free from added fusible ingredients.

It would be interesting to know whether, in cases in which this has been done, any flaking-off of the silica cement has occurred when the retorts were brought into use. We have patched our retorts in a very thorough manner, and they have stood up remarkably well until the first scurfing, but then a very great proportion of the material has come off, and the flakes have been so soft that they could easily be reduced to dust between the fingers. I should also like to ask whether, in Mr. Green's opinion, there is a critical temperature of vitrification below which the time factor is of small importance.

The PRESIDENT: I am very much obliged to Mr. Shapley for his suggestion that written contributions should be invited, and I shall be grateful for any contributions that are sent in. That is precisely what was in my mind when I said that if we pooled the knowledge that is in existence we should go a long way towards solving our refractory problems.

MR. GREEN REPLIES.

Mr. GREEN, replying to the discussion, said: I should like to thank Mr. Frank West for the encouragement he has given us, and always gives us, in connection with our study of refractory materials. Our work on the permeability of refractory materials is going on very well indeed, and, if I may rather anticipate matters, I do not think there will be any difficulty about the presentation of a report on that subject at the next meeting. In reply to Mr. Belton, I would say that I put forward the idea of using zonal materials, not as a particularly new idea, but as one which is not by any means generally accepted. I should like to have a clear definition of what is meant by " aluminous material " before I pass an opinion as to the adequacy of such material for use in a vertical retort. Some do not serve well, because, as we know, aluminous materials tend to contract, or to continue to contract during usage, and if that feature is likely to occur in a vertical retort there is no end to the damage that might result. With regard to flaking and spalling, I would suggest to Mr. Belton that the trouble he referred to when discussing jointing material would be a spalling effect, an effect that one would look upon as a mere thermal strain—and to my mind there is a definite difference between a thermal strain and a flaking effect.

I thank the President for his suggestion that we should pool our knowledge. Believe me, the Refractories Research Association would be delighted with any help it can get of an industrial nature, because we know well that we have to collect a tremendous amount of industrial data before our researches can be of much use to the industry. We should welcome from members of the Institution any information they care to send us in regard to their problems and the effects they have noticed in their retorts.

Reference has been made by the President to the investigation of the nature of flaking effects by taking plaster casts. I have investigated a number of retorts by going up them when they have been dirty, and I should say that the taking of plaster casts on the inside of a retort, with all the dirt in one's eyes, would be a delightful occupation. [Laughter.]

With regard to Mr. Shapley's remarks, it seems to me that cold patching serves two purposes. In the first place, by so doing we endeavour to put a surface on the retort, which certainly may come off during the first scurfing, but, in the second place, the patching tends to knit up the material at the surface; thus, although the actual skin of the patch may come away during the first scurfing, I think there is definitely an advantage in cold patching. I have come across instances in which it has behaved exceptionally well.

I cannot quite get the hang of his question with regard to the critical temperature of vitrification. I was wondering whether he was referring to a silica material, or to one which might be looked upon as a siliceous material, containing about 91 p.ct. of silica. We know that siliceous material does definitely harden during use, without a tendency to contract; and this in itself is an advantage. I suggest that this can take place at any temperature above 1300° C.

1st Report of the Corrosion of Pipes Sub-Committee

The Corrosion of Pipes Sub-Committee is pleased to submit its 1st Report to the General Research Committee of the Institution of Gas Engineers. Th Report relates to " The Protection of Pipes against External Corrosion," and covers the year 1929-30, during which period the members of the Sub-Committee were: Albert Stokes (Chairman), J. E. Blundell, Chas. F. Botley, D. Chandler, J. G. Clark, Fred Davies, Stephen Lacey, H. D. Madden, W. E. Price, R. Robertson, R. H. Ruthven, F. P. Tarratt, Dr. J. S. G. Thomas, and John Wilkinson.

This 1st Report of the Corrosion of Pipes Sub-Committee of the General Research Committee of the Institution of Gas Engineers, is to be considered as supplementary to the report of the Wrought Iron Tubing Committee presented to the Institution in June, 1925, and included in the Transactions of the Institution for 1924-1925. That report gave " details of an investigation carried out to examine the respects, if any, in which samples representative of the steel and iron nowadays supplied to the Gas Industry differ among themselves and from pre-war supplies of these materials in respect to rusting and corrosion." The subject was examined particularly from the point of view of the *internal* corrosion of gas services. It was shown that a tube made from genuine English puddled wrought iron was superior to steel, and more especially to some of the samples of steel then supplied. Subsequently, a Specification for Wrought Iron Tube Strip and a Specification for Wrought Iron Tubes and Fittings were prepared and were adopted by the Council of the Institution on February 9th, 1927. The List of Approved Makers of Wrought Iron Tube Strip, issued in accordance with the former Specification, was revised on September 17th, 1930, and included in the reprint of the Specifications then published.

It may be appropriately mentioned here that the increasing practice of distributing partially dried gas is tending to reduce the *internal* corrosion of mains and services. In future, therefore, it may well be that, so far as *internal* corrison is concerned, the choice of material as between cast iron, wrought iron, and steel will depend less on considerations of resistance to corrosion and more upon first cost and mechanical suitability.

On the other hand, the protection of pipes, service pipes in particular, against *external* corrosion becomes increasingly important because of the increasing cost of reinstatement of pavings that must be broken up when the service pipes have to be renewed.

The present investigation has involved the examination of various materials and methods used for the protection of pipes against *external* corrosion. The experimental work has been carried out in the Laboratories of the Gas Light and Coke Company and of the South Metropolitan Gas Company.

AGENCIES OF EXTERNAL CORROSION.

External corrosion may be due to one or both of two causes, namely :—

(*a*) To the corrosive power of the soil in contact with the pipe—Contact Corrosion.

(*b*) To the presence of stray electric current from tramway or other electric systems—so-called Electrolysis.

It is useful to distinguish between these two types of external corrosion because, as will be shown later, certain protective methods which are adequate against contact corrosion are inadequate against electrolysis. For instance, cement offers considerable protection against contact corrosion, but not against electrolysis.

CORROSION A GALVANIC PHENOMENON.

The general problem appears to be as follows :—It is now generally accepted that corrosion at atmospheric temperature is a galvanic phenomenon. It occurs at points where an electric current passes from the metal into some conducting liquid, usually an aqueous solution. The electromotive force may arise from the chemical

energy of the metal itself (in which case it is small—of the order of a volt) or it may be supplied from an external source, as in the case of electrolysis by stray currents. In this case, the electromotive force may be large, and corrosion correspondingly rapid.

A protective coating that shall be permanently waterproof must have the following properties :—

1. It must possess high specific electrical resistance.
2. It must be resistant to chemical attack.

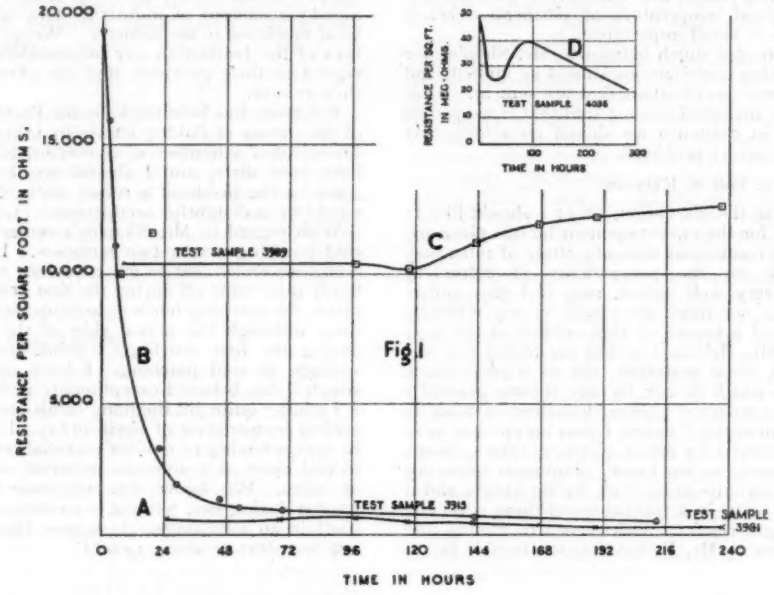


Fig 1

Exclusion of Water Imperative.

Corrosion of the metal can be prevented—

(1) By preventing water coming in contact with the metal.

(2) By applying a reverse electromotive force so that the metal is either neutral or cathodic.

3. It must be mechanically strong to resist possible damage during transport and handling.
4. It must be unaffected by age.
5. It must be easily applied to a pipe—preferably in the cold.

Available Protective Coatings.

Protective coatings that are available may be classified

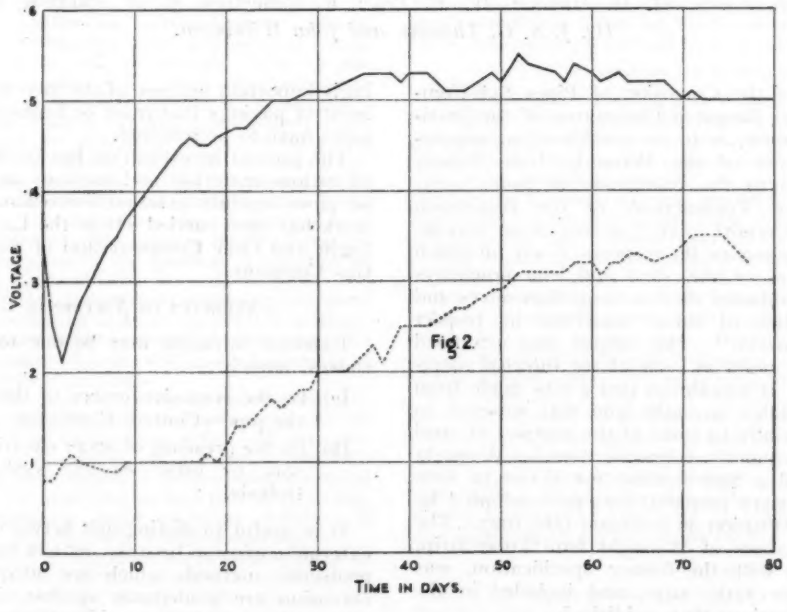


Fig 2.

In practice, method (2) is, generally speaking, impracticable, and the problem resolves itself into providing a protective coating impermeable to water.

It should be added that in the case of impressed currents, a third method is possible, which consists in connecting the metal to be preserved to some other piece of metal called an earth-plate, suitably situated, so that the current passes from the latter and corrosion is transferred to it. In the present work, attention has, however, been confined to method (1).

as—paints, bitumens, and pitch, impregnated fabrics, Portland cement, and metallic coatings.

Most paints contain oils such as linseed, china wood, &c., and these mixed with pigments and coming into contact with alkaline soil, saponify and soon lose any waterproofing property they may originally have possessed. This Report is chiefly concerned with an examination of the waterproofing qualities of various paints and the retention of this quality on immersion of the material in solutions.

Experimental Methods of Testing.

There are two simple methods for determining the penetration of water or other solution through the protective coating. The one adopted by the Gas Light and Coke Company depends upon a measurement from time to time of the effective electrical resistance of the protective coating applied to the pipe and immersed in water or solution. This method affords useful information regarding the course of the penetration of water, &c., as with increasing depth of penetration the electrical resistance of the protective coating will generally decrease until it reaches a constant value indicating penetration to the underlying iron pipe. The second method, adopted by the South Metropolitan Gas Company, depends upon the measurement of the electromotive force developed between the metal of the protected pipe and a copper plate immersed in water or other solution. An electromotive force is developed at once if and when water penetrates to the pipe material. It is also possible to discriminate between penetration through the actual protective coating and penetration to the metal through minute pinholes in the protection. In the latter case the electric current flowing will, owing to the very large resistance in the circuit, be very small compared with that flowing when the coating itself has been more completely penetrated.

The two methods have been found to give comparable results when testing exceptionally good coatings, but for less perfect coatings the results were not always reconcilable. The differences, however, were unimportant so far as this Report is concerned.

Electrical Resistance of Coatings; Figs. 1 and 2.

It seems desirable that the requisite electrical resistance of coatings should be specified, but at present there is insufficient information to enable the Committee to do this. For the present the results can be regarded as comparatively only; Figs. 1 and 2 in the Appendix show typical results of the experiments that have been made for the Committee. The data in Fig. 1 were obtained by the method of the Gas Light and Coke Company. Curve A is a case of a coating of low resistance which changed very slightly after immersion in water for 240 hours. Curve B refers to a coating which had a fairly high electrical resistance initially, but, owing to rapid penetration of water, fell to a low value very quickly. Curve C is an interesting case of a coating which increased in electrical resistance during the period of the test. Curve D refers to a coating which varied in electrical resistance but within the period of the experiment remained in the megohm order of resistance.

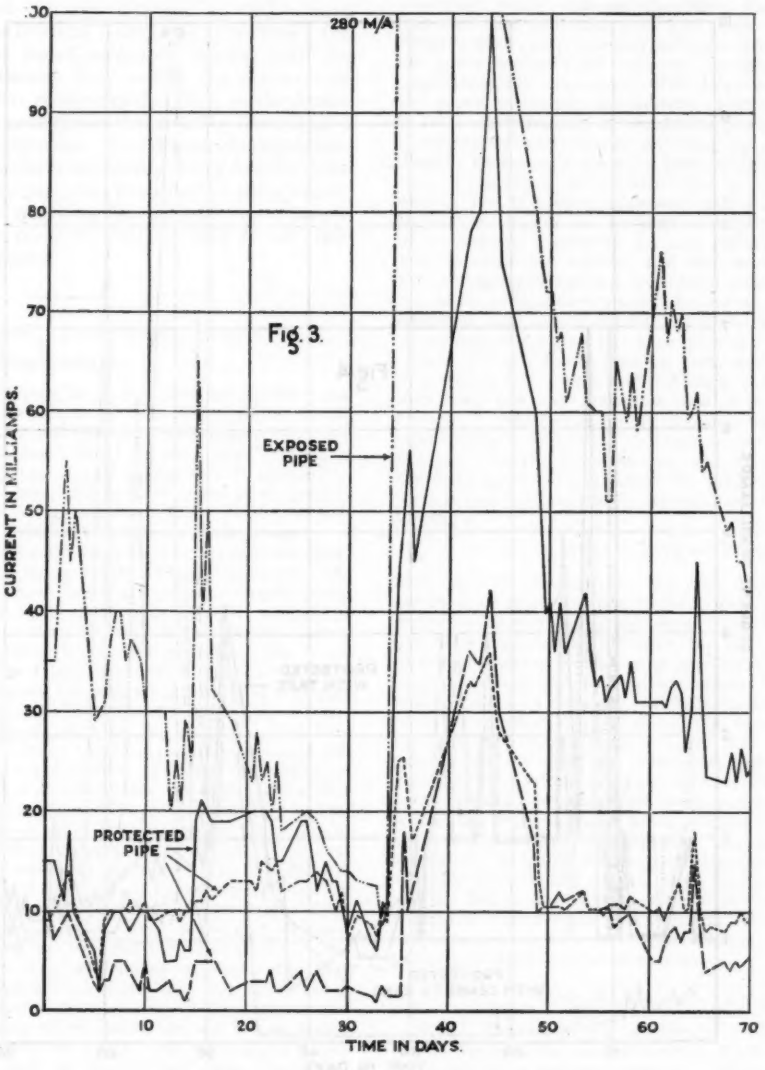


Fig. 2 represents results obtained by the method of the South Metropolitan Gas Company. The variations are similar to those shown in Fig. 1, a rise in the voltage being indicative of the penetration of the coating by water.

Measurement of Protection Against Electrolysis; Figs. 3 and 4.

For the purpose of determining the measure of protection afforded by various protective devices against so-called "electrolysis," samples of unprotected and protected pipes were inserted in a box 6 ft. square filled with soil.

The pipes were all arranged at the same distance from an iron plate about 6 ft. square. A current derived from a six volt battery was passed between each pipe and the plate and the magnitude of this current measured for each pipe. In every case the pipe constituted the anode. The results obtained are shown in Figs. 3 and 4 in the Appendix. In Fig. 3 are given the currents in milliamps flowing between the pipe and plate in the respective cases of (1) the exposed pipe and (2) pipes protected with protective paint. The soil in all cases was exposed to atmospheric conditions. It will be seen that the magnitude of the current was very much less for the protected than for the exposed pipe. The curves in Fig. 4 relate to pipes as above with the additional protection afforded by waterproof tape. In these cases the value of current is reduced to something of the order of 1/50th of its value in the preceding cases. This indicates the value of the waterproof wrapping for protecting the pipe against stray electric currents. It will be further noted that the current in the case of a pipe placed in a cement-sand mixture was very small for about 40 days, but thereafter the current was large. It would appear, therefore, that the protection against stray electric currents afforded by cement-sand mixture is only temporary, although observations show that this mixture is a fair protection against contact corrosion.

The sharp variations in the curves are indicative of water penetration. The boxes being exposed to atmospheric conditions the soil became wet in time of rain and, by draining and evaporation, became drier when no rain fell.

Danger from Faults in Coating.

A word of caution is necessary as regards the protection of pipes by painting or otherwise. An examination of the pipes after their removal from the soil revealed that in the case of the unprotected pipe, electrolysis was distributed all over the surface of the pipe. A marked characteristic of the protected pipes was that the centres of electrolytic action were distinctly local in character. The whole surface of the pipe was *not* pitted in these cases as in the case of the unprotected pipe, but the pits were very considerably deeper, and moreover were deeper the greater the number of protective coatings. This is quite understandable, when it is considered that the greater part of the current flows from points of the pipe at which the protective coating is weak electrically. Such weak spots are likely to be less numerous the greater the number of coats applied. It is to be seen, therefore, that if pipes are to be protected against Electrolytic Corrosion, such protective coatings as are employed must be well applied otherwise effcient protection against corrosion may be achieved only at the expense of an intensified local electrolysis.

With contact corrosion, faults in the protective coating have not quite such serious effects as with electrolytic corrosion. Nevertheless, the importance of complete protection cannot be over-emphasized, because one local

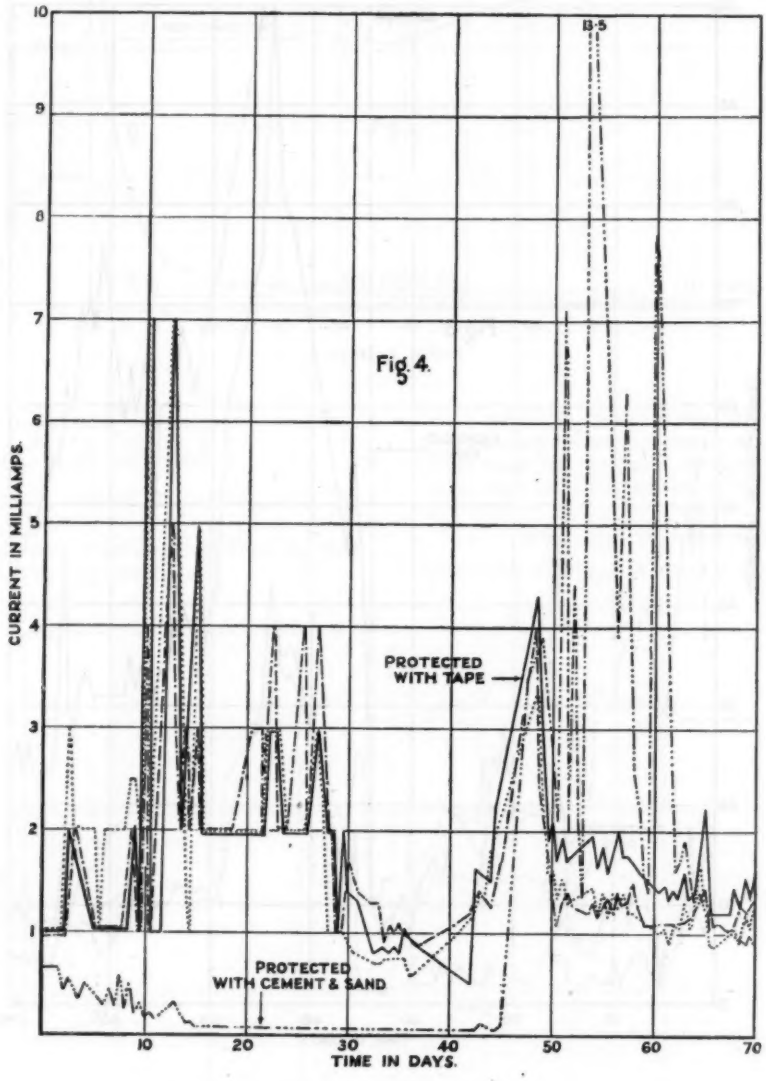


Fig. 4.

defect in a service pipe is sufficient to render the whole pipe unsound and to necessitate its replacement.

Need for Specification and Further Work.

The Corrosion of Pipes Sub-Committee realize the need for specifications for protective coatings and for a generally accepted method of testing. The available information, however, is not yet sufficient for this.

The present investigation, though incomplete, has already had important results. A considerable number of samples of pipes coated by Tube Manufacturers have been tested and the results made known to the manufacturers concerned. Many of the Tube Manufacturers have been working at the problem themselves, and have substantially improved their pipe coatings. For this reason, and others, the Sub-Committee have not thought it desirable to publish particulars of individual tests.

It is the intention of the two Companies which have carried out the experimental work to continue the investigation, and the Sub-Committee hopes that the information obtained thereby may justify the preparation of a further Report. It is recommended that, in the meanwhile, Gas Engineers throughout the country should give the subject the close attention it undoubtedly deserves. Part, at least, of the protective coating for a service pipe must be applied after the pipe has been laid in the ground, and one of the chief difficulties lies in making a sound job of this. The best possible coating will be of little value if not carefully applied.

Mr. R. H. Ruthven presented the foregoing report.

DISCUSSION.

The President: This report is a very interesting one, and the information it contains affects us all. The graphs at the end, showing the resistance afforded by various materials, are very instructive. There is one point I cannot quite understand concerning the pipe rolled in cement and sand. It appears to have failed after about 40 days, and to have failed more quickly than the pipe which was not protected at all. That does not appear to be logical, and I should like to hear more about it.

Mr. L. H. Sensicle: I should like to say that I am thoroughly in favour of the method of using lower voltages for testing the wrapping of pipes. In 1928 we started a series of experiments, in which different pipes were wrapped with different wrappings and buried in the soil at a certain distance from a central copper cathode. Various interesting facts emerged from the tests, which were carried out over a period of twelve months. A voltage of about 6 was maintained throughout a year, and readings were taken by means of a millivolt-meter each day of the current passing to individual pipes in the ground. One fact which emerged was that within about a month one could tell with certainty whether or not a certain wrapping was going to be successful. There was a small current passage within that time in wet weather, so that it was not really necessary to run the tests for a whole year. I think that fact might be of use to anyone who is testing different types of material. The best type of wrapping in that particular case proved to be bitumen hessian, which was prepared by the Gas Company and not by outside manufacturers. I can also bear out the contention that wrapping must be extremely carefully done. A piece of wrapped wrought-iron pipe supplied by the makers showed two pinholes of corrosion. There was no reading given for the first few days after the pipe was buried in the soil, but after rain a reading immediately appeared and continued throughout the year, and when the pipe was taken out of the soil it was found to be almost eaten through. In every case unwrapped pipes were put into the soil, and we found that these had been corroded right across. In conclusion, I would say that from personal experience I can recommend this method of electrolysis in the soil for testing various types of protective coatings or wrappings for pipes.

Steel *versus* Iron.

Mr. Stephen Lacey (Gas Light and Coke Company): Inasmuch as I am a member of the Committee, and have inscribed my name in the report, nearly all that I have to say is contained in the report. As Mr. Ruthven has said, we must keep an open mind in regard to this question of steel *versus* wrought iron, and also, I might add, in regard to the question of steel *versus* cast iron. For the last twenty years the relative merits of cast iron and steel have been argued, and I think all will agree that cast iron has largely held its own, because the experience of a century has shown that it has an extraordinarily and surprisingly high degree of resistance to corrosion in normal circumstances, and, secondly, there has been no convincing proof forthcoming that the wrapping of steel pipes will be permanently effective. The Committee was not directly concerned with this question of steel *versus* cast iron, of course, but it does arise as the result of the Committee's work, and I think it right to raise the question in this discussion. It does seem to me rather surprising that the manufacturers of steel pipes, who are interested in obtaining an effective protective coating, have done relatively little in the last twenty years. The wrapping supplied now with steel pipes is, I think, substantially the same as that supplied twenty years ago. It is quite true that that wrapping has in some circumstances stood up extraordinarily well. In other cases it has failed rather badly; and I think it is a very good thing that this question of wrapping should have been raised again and should be studied thoroughly, as it is being studied now, not only by this Committee but by the manufacturers also.

There are available to-day protective coatings, which are not wrappings, but really asphaltic coverings, which hold out great promise, to my mind, and I can see that, if those coatings prove to be as good as they appear to be, the relative positions of cast iron and steel may be altered. The Committee, however, was concerned really with service pipes, for which the alternative materials are not cast iron and steel, but wrought iron and possibly steel; and, whether wrought iron or steel is used, under the great majority of ordinary conditions some protection is unquestionably necessary. The importance of protecting service pipes, of course, has become greater than formerly because in these days the cost of reinstating paving is so high. Clearly, if reinstatement costs are anything up to £2 per square yard, there is very good reason for increasing the life of a pipe, if you can. I am not at all confident that wrapping represents the last word. The wrapping material itself should be thoroughly impregnated; unless the hessian is properly impregnated it may be a source of weakness, because ultimately the water finds its way through the textile, and this breaks down the coating. The wrapping is nothing more than a means of holding in place the pitch or bitumen material. Stress has been laid by Mr. Ruthven, and in the report, upon the importance of thorough wrapping, and a case has been quoted in which a wrapped pipe corroded locally faster than an unwrapped pipe. I do not think it has been mentioned, but I think it should be, that this corrosion was not soil corrosion but was electrolytic corrosion. Finally, I would draw your attention to the last section of the report, which is headed "Need for Specification and Further Work." As Mr. Ruthven has said, we have only just started. We have more or less stated the problem, however, and if we state a problem accurately we have got a fair distance towards solving it.

A New Type of Bandage.

Dr. G. W. Anderson: My only regret is that the investigators have not been able to prescribe a satisfactory bandage or protection for wrought-iron pipes. I know a great deal of work has been done by Dr. Thomas, but he is silent. In the course of my consulting work I was approached by some people who have circulated the gas industry within the last eighteen months with regard to a bandage which bears a trade name, and which is rather extraordinary in more than one way. I examined the bandage very carefully, and found that if it were applied in a careful manner it offered electrical resistance of the order of 10,000 or 20,000 ohms. The material is hessian cloth of rather open texture, impregnated with a kind of vaseline, which softens or drips at about 70° C. That texture seems to absorb the vaseline in varying degrees. The iron tubing underneath it retained its bright surface after immersion in a bath for 28 or 30 days, whereas the control piece was pitted. I have not been able to find a satisfactory solution of that phenomenon, and I wondered whether the investigators responsible for this report had come across this particular bandage and whether they could throw any light on the phenomenon.

Use of Pitch in Troughing.

Mr. C. F. Botley (Past-President): I happen to be a member of this Committee, and, therefore, what I have to say must be regarded as a personal matter. While we are searching for definiteness in regard to the protection of service pipes, and having regard to the great cost of reinstatement, many of us are in the habit of using pitch in troughing, and I believe—in fact, I thought it was agreed—that if this is done properly it does afford protection against external corrosion by soil or electrolysis. As a practical contribution to this discussion I wish to put this forward as a method which I think is as hopeful as any method available to us to-day for the protection of service pipes.

The President: We are grateful to Mr. Botley for having raised that point. I have never known a service to become corroded when laid in the manner he indicated—run in with hot bitumen in a trough—though I have seen pipes absolutely corroded when they have been coated with bitumen wrapped with hessian outside the bitumen, and then coated again with bitumen.

Mr. Lacey: I can confirm what Mr. Botley has said about troughing, from my own experience. Our difficulty, however, in London—and I have no doubt the same difficulty is experienced elsewhere—is that it is very difficult to arrange the trough-

ing. We have to run service pipes under and over various obstacles, and the obstacles are so many that it is much easier to apply a wrapping.

REPLY TO THE DISCUSSION.

Mr. RUTHVEN, replying to the discussion, said: The Committee would be delighted to have particulars of anyone's experience and the results of tests. We feel, of course, that the more investigators we have working on this problem, the sooner it is likely to be solved. With regard to asphaltic coatings, it is the case that cast-iron pipes so coated can be obtained. We are engaged now in laying about 5000 yards of water main which has been so coated, and its appearance suggests that it should be practically everlasting. The coating is hard, it can withstand transportation very well, it has a defined boiling point, of course, quite an appreciable thickness—about ¼-in.—and it certainly appears to be a thoroughly good external protective medium. If such a material can be applied to the smaller service pipes, I imagine that the result should be equally good, except, of course, that there is always the difficulty of the joint with the main and the sockets at the junction of one length and the next. We do hope that something of that nature will prove to be more satisfactory than some of the wrappings examined.

In regard to the point raised by Dr. Anderson, the results of individual tests, of course, are not given in the report. The material he refers to has been tested very thoroughly, but it is quite impossible to give the results of particular tests, for obvious reasons.

As to pitch in troughing, we realize that, if it can be done, and if it is done thoroughly, it is a perfect job, but we wanted to find something which could be applied more easily; we feel that the problem will certainly not be solved until something of a much better nature is forthcoming, and which can be more easily applied.

I am afraid I cannot answer the President's question, but perhaps I could find out from Dr. Thomas, who made the particular test referred to, and who probably has an explanation. At the same time, there are one or two points we cannot explain. For instance, in regard to the curve in fig. 1, we do not know why the insulation should have improved after a period. The question raised by the President may also be one of those which we cannot answer.

5th Report of the Liquor Effluents Sub-Committee

The members of the Liquor Effluents Sub-Committee for 1929-30 and of its Research Staff at the date of the Report were:—Chairman: Chas. F. Botley, M.Inst.C.E., M.Inst.Gas E. Members: Dr. T. Lewis Bailey, F.I.C., and Dr. H. T. Calvert, M.B.E., F.I.C.; P. N. Langford and F. Lee (Co-opted Members for the period of research work at Coventry and Hinckley); Dr. A. Parker, F.I.C., M.I.Chem.E., W. E. Price, Dr. E. W. Smith, C.B.E., F.I.C., J. Wilkinson, O.B.E., and Prof. J. W. Cobb, C.B.E., B.Sc., F.I.C. (Honorary Secretary). Research Chemist: A. C. Monkhouse, Ph.D., B.Sc., A.I.C. Research Assistant: W. Etheridge, B.Sc.

FOREWORD BY THE CHAIRMAN OF THE LIQUOR EFFLUENTS SUB-COMMITTEE (CHAS. F. BOTLEY, M.Inst.C.E., M.Inst.Gas E.).

It is now some time since the Sub-Committee's First Report, which included the able exposition by Dr. Parker on the subject, was issued, and it may therefore be convenient to review the position generally.

Progress undoubtedly has been, and is being, made, as reference to the published and present Reports must show, but the urgent matter of the disposal of crude ammoniacal liquor is now part of the problem. It is obvious that a solution in greater or less degree of the ammonia problem will probably also mean a solution of the effluent problem.

The character of the work carried out by the Sub-Committee on behalf of the Institution and in association with the University of Leeds, through Professor Cobb and the Research Chemists, has been such as to establish confidence with others outside the industry interested in the problem, and the contributions which have been made to other bodies by Dr. Parker and Dr. Monkhouse have been important contributions to the better understanding of the difficult problem which the Sub-Committee have set out to attempt to solve. The Sub-Committee have been represented at Conferences of the Royal Sanitary Institute and before the Joint Advisory Committee on River Pollution. A close touch is being kept with the work of Mr. Roberts, of the Experimental Station of the Ministry of Agriculture and Fisheries at Alresford, on the influence of toxic constituents on fish life.

From time to time appeals have been made for co-operation or pooling of knowledge, because it is appreciated that there are other research workers dealing with the problem outside the Sub-Committee's activities, and it is quite obvious that a number of undertakings have worked out their own salvation in the disposal of effluent. Having regard to the object of the Sub-Committee's work, it appears unfortunate if methods of disposal which are actually in successful use cannot be made known for the benefit of the industry generally, but in this connection it is only fair to say that methods of disposal are now being investigated, but in regard to which it is not possible at the moment to give any definite information. Contributions to the Technical Press from Halifax and Bolton will be recalled.

Numerous applications for help or advice have been received, and with the co-operation of Professor Cobb, and following the information available in the Reports, have been dealt with in correspondence or by personal visits. These inquiries, which occasionally come from Borough Surveyors or Public Authorities, reach the Sub-Committee direct or through the Institution or the National Gas Council (the Officers of which have rendered much assistance in regard to legal aspects of the effluent question). In a good many cases when advice has been given it is disappointing not to hear further as to the result, as this would assist in dealing with similar difficulties elsewhere. It may, however, be assumed that the assistance rendered has been of service.

It may be useful to indicate briefly the nature of some of these inquiries, which arise under one or other of the following headings:—

(*a*) Trouble with Sewage Authorities following an alteration in the method of carbonization at the particular gas-works.

In regard to this trouble, and sometimes as to the other inquiries, the stereotyped reply has repeatedly been given that the effluent liquor should be cooled and free from sediment, and should be run into the sewers at a regular rate even if storage tanks become necessary. Also, that endeavours should be made to reduce the quantity and improve the composition (from the sewage point of view) of the effluent liquor. Further, that "devil" liquor, which, by the way, does not arise when liquor is concentrated and not made into sulphate or other product involving a still, should be disposed of separately by evaporation on furnace or producer bars or by fine spraying vertically in the base of a chimney containing heated gases. It is, however, emphasized that the success of the last-mentioned methods must depend upon care in application.

(*b*) Difficulties arising when the local sewage works have not been kept of size adequate to the growth of the neighbourhood or have altered the system of disposal.

In one such case, in negotiation with the Ministry concerned it was suggested to the Local Authority that if their sewage works were brought up to date the effluent could be treated without real difficulty. The question of the cost of dealing with effluent liquor sometimes arises. This is a matter which is of local importance and needs to be

considered in a reasonable manner. A case is known where the charge is of such an onerous character as to call for comment.

(*c*) Trouble when the sewers have to be utilized as a means of disposal because the old methods are no longer possible.

An old and crude method of disposal has been the uncontrolled discharge of the waste liquor on to land or on to beds of breeze or clinker or even into soakage pits, and this sooner or later is likely to give trouble, especially if there are any rivers or streams or wells in the neighbourhood. When such troubles have arisen and attempts to overcome them by discharge into the public sewers have been made, misapprehension has not infrequently arisen on the part of officials of Local Sanitary or Sewage Authorities as well as in the past of local gas-works undertakings. In view of the fact that it has, of course, been definitely shown that a controlled mixture of sewage and effluent can be adequately treated on the ordinary form of bacteriological filters, it has been comparatively easy to dispose of such misapprehension.

(*d*) Information in regard to constructional details of plant used in connection with effluent.

The provision of large settling, cooling, or storage tanks in order to regulate the flow of effluent into the sewer has led to questions as to material, and reinforced concrete tanks are satisfactory.

(*e*) Information in regard to the chemical composition of sewage or effluent and as to the possible treatment of such effluent.

It has on several occasions been of great advantage to have reliable and independent analyses of effluent. This is work which requires special knowledge. Possible methods of treatment have been referred to, but in one case, where a large undertaking has no ready means of final disposal other than discharge to an adjacent waterway, a system of phenol recovery is under consideration and may prove of value in similar cases. Information has been sought in America and in Germany on this aspect of the problem, and it is fair to say that in the last-named country the process is in successful operation. There are visions of being able to devise such a plant as would be suitable for medium-size works.

(*f*) Disposal of crude ammoniacal liquor, which is really an ammonia problem.

Undertakings in trouble with the disposal of spent effluent not unnaturally consider discontinuing any working-up process, and then the disposal of the crude liquor arises. The industry must obviously associate itself with every endeavour which is made to maintain and improve the conditions of the rivers and streams of the country, which often furnish some part of the water supply, and therefore any method of disposal which may affect such streams is to be deprecated. Conditions will, however, vary, and in some cases the crude liquor to be disposed of is small in quantity and weak in strength and there is ample dilution. There are, however, means of disposal on a works, as, for instance, for quenching purposes and in the furnaces, which should be taken into consideration. Under exceptional circumstances crude liquor has been taken into the sewers by arrangement, and the final effluent has been brought into conformity with the stringent requirements of the responsible authority.

From a consideration of the Committee's work in the past and the programme for the immediate future, it will be seen that theory and practice are associated, and it is constantly realized that the prevailing low prices for liquid bye-products makes the economic aspect of any method of effluent treatment or disposal of imperative importance.

GENERAL INTRODUCTION.

By the Livesey Professor (JOHN W. COBB, C.B.E., B.Sc., F.I.C.).

In submitting its Report, the Sub-Committee would like to emphasize the fact that its work is not confined to investigations of the systematic kind dealt with below, the results of which lend themselves to a connected account and to presentation in the form of a printed Report. One of the most important functions of the Committee has been to deal in an advisory manner with questions of immediate importance and urgency raised by gas engineers throughout the country. This has been effected mainly through Mr. Botley, Chairman of the Committee, and Dr. Monkhouse, the Research Chemist. It has made considerable inroads upon the time of Dr. Monkhouse, and has justified the appointment of Mr. W. Etheridge as Research Assistant, which secures that in the absences of Dr. Monkhouse, so necessitated, the experimental work in progress can be given a continuity which would otherwise be impossible.

The Sub-Committee cannot, of course, take in hand the detailed preparation or examination of schemes for dealing with effluent liquors, but it can, and does, give such general advice and assistance as come within its scope and resources.

Dr. Monkhouse read papers before the World Power Conference in Berlin and the Sewage Managers' Association at York on the effluent question, both of which should serve a useful purpose.

Dealing now with the experimental work, the results of which are reported below, this has proceeded in several directions, and details are given under their appropriate headings. At the Coventry Gas-Works, the operation of a cyclone tar extractor on a Glover-West setting of vertical retorts has been tested out, and the results have been reported along with those previously obtained by the use of the Lodge-Cottrell electrostatic tar precipitator at Hinckley. A test of considerable duration and complete success has been made on the disposal of effluent liquors by evaporation on the bar grates of gas producers at the Hinckley Works. An evaporation has been obtained which corresponds with the disposal of 37 per cent. of the total effluent liquor produced, consisting of the whole of the devil liquor and 27 per cent. of the spent liquor from the still. No serious trouble of any kind has arisen in the operation. The biological purification of effluent liquors carried out on the Foleshill Bacteria Beds at Coventry, constructed for the purpose, has received further careful examination. The results suggest that this method it technically effective but at a heavy monetary expenditure. Further inquiry has been directed into the position of processes recently proposed and under trial on large-scale plants, particularly in the bye-product coke oven industry, for the extraction of phenol, always present in effluent liquors. Dr. Monkhouse visited Germany in July, and his report on some of these plants is given below. The results obtained would suggest the advisability of getting the phenol extraction process tested thoroughly under gas-works conditions, where its technical and commercial possibilities for the Gas Industry can be more exactly ascertained. In this connection it has to be remembered that the higher tar acids, in addition to monohydric phenols, have to be taken much more seriously into account in gas-works than in coke oven effluents, particularly where vertical retorts are employed. For this reason laboratory experiments have been conducted at Coventry in which the action of benzole and mixtures of benzole and aniline in the extraction of phenol and the higher tar acids from liquor have been subjected to examination. Interesting results have been obtained, and the laboratory experiments are to be followed up by studying the effects obtained on a semi-scale plant which has been already erected. In this plant the counter-current flow of the liquor and solvent will be adopted.

The Sub-Committee would like to thank Dr. Monkhouse and his assistant, Mr. Etheridge, for the zeal and capacity they have shown in its service, and to make the acknowledgments due to others who, by their co-operation, have made its work possible. Of these, special mention may be made of Mr. Lee, of Hinckley, Mr. Langford, of Coventry, and their respective Committees and staffs, for facilities and assistance continuously and freely rendered, and to Dr. Happold, of the Department of Bacteriology in the University of Leeds, for his help and advice on the bacteriological side.

SUMMARY OF 5TH REPORT.

The section of this report relating to methods of reducing the higher tar acid content of ammonia liquor, deals with the final experiments made with a Lodge Cottrell electrostatic tar preciptator at the Hinckley Gas-Works. In the 3rd Report of the Effluents Sub-Com-

mittee a detailed description was given of the plant, its method of operation, and the results obtained. In the present Report the results of continued working are given together with analyses of the final ammonia liquor and the effluent obtained on distillation.

The removal of heavy tar before the condensation of liquor caused a marked reduction in the higher tar acid content of the liquor, as shown in Table A, which summarizes results from the same setting by different methods.

Thus the higher tar acid content of the liquor was reduced to 38 grams O_2 absorbed per 100,000 c.c., as compared with 170, or 140 when a closed liquor circulation system with a tar separator was used. The monohydric phenol content of the liquor was increased to 0·58 gram C_6H_5OH per 100 c.c. Monohydric phenols are more readily removed by solvents, evaporation, or bacterial treatment than are the higher tar acids, and do not give rise to the intense reddish brown colour which is so distinctive a characteristic of vertical and low-temperature liquors. The distillation of the modified liquor yielded an effluent which had a comparatively low higher tar acid content. The devil liquor had a phenol content of 1·124 gm. C_6H_5OH per 100 c.c., which was considerably higher than that obtained previously. This was, however, disposed of by evaporation on the producer bars of a setting of continuous vertical retorts.

TABLE A.

	Crude Ammonia Liquor.			Spent Liquor from Still (excluding Devil Liquor).		
	1.	2.	3.	1.	2.	3.
Higher tar acids, O_2 absorbed gms. per 100,000 c.c. (burette test)	170	140	38	145	115	24
Monohydric phenols, gms. per 100 c.c.	0·35	0·36	0·58	0·10	0·12	0·19
Oxygen absorption (4 hrs. 27° C.), parts per 100,000—						
Equivalent to phenols	623	641	1032	178	214	338
Difference figure	685	465	160	560	400	123

1. Without tar precipitator and without continuous closed liquor circulation.
2. Without tar precipitator and with continuous closed liquor circulation.
3. With electrostatic tar precipitator.

Although the electrostatic plant was of an experimental nature, the whole of the gas from a setting of continuous vertical retorts was treated from January to September, 1929, with satisfactory results. Precautions had to be taken to ensure that the gas was maintained above dew-point by lagging the mains and the precipitator or a tar with high water-content resulted. Attention is drawn to the fact that in cases where coals of high chloride content are carbonized, the deposition of ammonium chloride with the tar would result in corrosive action on the still on subsequent distillation unless preventive measures were adopted. Distillation tests of the tars were recorded showing that the tars condensed at the later stages of the condensation process were light oils floating on the surface of the liquor.

Experiments were made at the Hinckley Gas-Works on the evaporation of effluent liquors on the producer bars of a setting of continuous vertical retorts. Satisfactory results were obtained by replacing the water by devil liquor and preliminary experiments have shown that a mixture of devil liquor and spent liquor from the still can also be evaporated without injurious effects. If storage accommodation is available, 37 per cent. of the total effluents can be evaporated on producer bars. This effluent comprises the whole of the devil liquor and 27 per cent. of the spent liquor from the still. The actual reduction obtained in the oxygen absorption value would be 42 per cent. compared with 37 per cent. by volume.

In view of the success attained at the Hinckley Gas-Works by the early separation of heavy tar, it was decided to investigate a system of condensation at the Coventry Gas-Works, consisting of a liquor circulation system and a cyclone tar extractor in order to attain the same end. The tar extractor was of the Colman type and it was possible by the aid of a flap valve to regulate the velocity of the gas at the inlet of the cyclone. The system of condensation was altered so that the tar condensed in the circulating system, the cyclone tar extractor and the water tube condensers ran direct by separate main to the tar storage tank and was isolated from the main bulk of liquor.

Tests were carried out under varying conditions of velocity through the cyclone and with varying amounts of circulating liquor With a liquor circulation of 670 gallons per ton of coal carbonized, 74 per cent. of the tar condensed up to the outlet of the water tube condensers was brought down in the retort house and 2 per cent. in the cyclone tar extractor with the flap fully open and a velocity at the inlet of 11 ft. per second. With a liquor circulation of 500 gallons per ton the tar brought down in the retort house was on the average 56 per cent., and the following is a summary of the results obtained with different conditions of the cyclone.

Test No.	2.	3.	4.	5.
Back pressure, in.	1·8	1·25	0·25	0·75
Velocity of gas, ft. per second	30	21	14	16
Tar condensed, per cent.	20·3	19·6	3·8	8·6

Tar fog tests showed that the actual efficiency of the cyclone varied from about 20 to 70 per cent., according to the velocity of the gas. The circulating liquor was a closed system except for a very slight overflow. The analyses showed that 85 per cent. of the ammonia in the liquor was present as "fixed" ammonia and that the higher tar acid content, due to continuous circulation, was high, viz., 250 (burette test) gram O_2 per 100,000 c.c. The liquor from the water tube condensers showed a slight increase in the higher tar acid content with increased condensation of tar in the water tube condensers. A tar and liquor separator was installed at the condensers and the tar and liquor ran into their respective mains. The optimum operation of the cyclone is dependent on the velocity of the gas. Under working conditions where the pull necessary at the inlet retort house governor is a dominant factor a back pressure of 1 to 1·2 in. was adopted.

The influence of these modifications of the condensing system on the stock ammonia liquor was examined. The analyses show a marked reduction in the higher tar acids. In the ammonia liquor a reduction from 100 to 50 (burette test) gram O_2 absorbed per 100,000 c.c. was obtained and in the spent liquor from the still from 75 to 29. The total oxygen absorption of the liquor was reduced from 1428 to 1200 parts per 100,000 and the spent liquor from 900 to 714 parts per 100,000. Further tests will be made under winter load conditions, when a greater proportion of vertical retorts will be in operation.

The purification of the effluent liquor on the bacteria beds at the Foleshill Gas-Works, Coventry, has been continued. During the twelve months ending June, 1930, 7 million gallons of spent liquor have been treated with an average oxygen absorption value of 956 parts per 100,000. The average oxygen absorption value of the effluent admitted to the sewers was 98·5 parts per 100,000, *i.e.*, an efficiency of purification of 89·7 per cent. Experiments on the time of passage of liquor through the beds gave an average of 17 minutes. The cost of treatment for the period under review amounted to 11s. per ton of sulphate for the running costs, or 30s. 10d. if allowance is made for interest and depreciation.

A report has been made of a visit to Germany to inspect the recent developments of phenol recovery plants on coke ovens. In the Emschergenossenschaft area, covering some 300 sq. miles, ten plants were in operation, four in course of erection, and ten projected. The general principle adopted in these plants is the removal of the phenols from the liquor by washing with benzole, and the recovery of the phenols from the benzole as sodium phenolate solution by the use of soda solution. In the Ruhrverband area a plant has been erected in which active carbon is used for the removal of phenols from the ammonia liquor. Results of recent experience have been collected, together with approximate figures of the economic success of the benzole process of phenol recovery. The process would appear under German conditions to pay for the expenses involved or be profitable in cases where the phenol content of the ammonia liquor is above 0·3 gram phenol per 100 c.c. The content of phenols in English gas-works liquor is on the average 0·3 to 0·4 gram phenol

per 100 c.c., but it must be borne in mind in making a comparison that there are present in gas-works liquor amounts of higher tar acids, thiocyanate, and thiosulphate in excess of those in coke oven liquors. Direct experiment would have to be made on gas-works liquors before a pronouncement could be made.

Laboratory experiments have been made on the removal of phenol and higher tar acids by means of solvents. The percentage removal at various temperatures has been determined, using solutions of pure phenols and also ammonia liquor. Using benzole as a solvent, the cresols were more readily removed than phenol, but catechol as representative of dihydric phenols was only removed to a small extent. In view of the affinity of water for the higher tar acids, tests were made with basic solvents. With a mixture of 80 parts of benzole to 20 parts of aniline oil, 50 per cent. removal of higher tar acids was obtained compared with 8 per cent. with benzole alone. Further solvents are under investigation, both in static and counter-flow conditions, and a semi-scale plant has been erected to investigate the extraction of gas-works ammonia liquor with solvents.

Prof. J. W. Cobb: There are one or two things I should like to mention which I think should be emphasized in connection with this Committee. Its work is of two kinds. One portion of it is the experimental work of investigation. That is of a systematic character, and the results can quite suitably form the subject-matter of such a report as you have before you this morning. But there is another branch of its work which is time-consuming and very important. The Committee was appointed in order to be of the maximum service in assisting gas engineers in their problems of effluent disposal. That assistance can be rendered, of course—we hope it is very valuable assistance—by the investigations, but there is another kind of assistance, which can be rendered on request from individual gas engineers who are having any kind of difficulty or are in any uncertainty as regards their effluent disposal.

The President: I should like to place on record our appreciation of the indefatigable service of Mr. Botley to this Sub-Committee. Mr. Botley has done most valuable work. I think you will agree when you study this report that some very tangible results have been obtained, and the Committee has been able to be of valuable service to many undertakings which have been troubled with their effluents. Thefore, I am sure I shall be voicing your wishes when I express our deep appreciation of Mr. Botley's services. [Loud applause.]

Mr. C. F. Botley then outlined the work that has been done by the Committee.

Continuing, he said: I was particularly impressed with the fact that at a conference of the Royal Sanitary Institute the other day there was a great deal of reference to the question of river pollution, and this touches us some time or other. Therefore, I say quite definitely that any haphazard or careless methods of disposal which may have existed in the past or might exist in the future cannot be continued without trouble to those concerned; and it is with the hope that we may do something before our labours are concluded to be of real assistance, more than perhaps we have been in the past, that we are constrained to go on with what is, after all, a very difficult task.

Dr. A. C. Monkhouse then gave an abstract of the report.

DISCUSSION.

Dr. A. Parker: I have really nothing much to add to what has been said by Prof. Cobb, the Chairman of the Committee, and Dr. Monkhouse on the technical side, but I should like to emphasize that there is a distinct movement towards the improvement of the condition of the rivers and water supplies of this country. Mr. Botley has referred to the conference of the Royal Sanitary Institute which was held last week, or the week before, which emphasized the number of interests that are concerned with the purity of rivers; but I think the most important factor is that with improved sanitation and more cleanly habits of the people more and more reasonably pure water is being required every year; and quite apart from requirements of this nature, many industries need water comparatively pure for their industrial processes. In certain trades small impurities in the water will upset the whole process and involve the works in considerable expense. As time goes on new sources of raw water have to be found, but these cannot be found so readily now in underground wells which are gradually being taken up; and it is fairly clear that eventually more and more rivers, many of which are at present to some extent polluted, will have to be used as the sources of raw water for subsequent treatment for supplies for domestic and industrial purposes. There is no doubt about it that the work of this Effluents Committee has been extremely valuable, not only in helping the different gas undertakings, but also in helping the sewage authorities and others to understand the problem and to look at it in a reasonable manner. The Water Pollution Research Board of the Department of Scientific and Industrial Research has followed this work with considerable interest, and I thought the members of the Institution would be pleased to know that, through the kindness of the President of the Institution, copies of all your reports have been supplied to members of the Water Pollution Research Board. They have taken very much interest indeed in the results obtained, and the experiments and methods have been briefly described to them and discussed at more than one of the Board's meetings. In the report before you there is mention of evidence having been given before the Joint Advisory Committee on River Pollution set up by the Minister of Health and the Minister of Agriculture and Fisheries. The Chairman of your Committee, Mr. Botley, and Mr. Smith, of the National Gas Council, together with Dr. Monkhouse, gave evidence before that Committee; and it was much appreciated.

At the present time for most works the best way out of the difficulty of disposal of the effluent is to reduce the volume after evaporating the devil liquor, by spraying into chimneys or on producer bars, or both, as much of the still effluent as possible. Dr. Monkhouse has shown that 37 p.ct. of the effluent liquor can be disposed of in this manner; and although the volume is 37 p.ct., the actual improvement, so far as disposal is concerned, is equivalent to 40 p.ct. The remaining liquor might be put into a storage tank so that it can be run in constant and regulated quantity into the sewers of the local sanitary authority. The Joint Advisory Committee on River Pollution has realized that streams in this country will probably benefit most by trade wastes, in many cases, being dealt with by the sewage authorities, who are experts in this sort of work; and in the Second Report of the Joint Advisory Committee it is recommended that in many cases trade waste should be admitted to the sewers for purification at the sewage works by arrangement with the local sanitary authority under certain conditions. Of course, safeguards are necessary, and these might include preliminary treatment at the particular manufacturer's works, with other conditions as regards regulation of rate of flow, which should be arranged locally. These are all the points I have to raise, but I thought it would be of interest to the Institution to know that sewage authorities and various other bodies have taken a keen interest in this work and have followed it very closely.

Mr. A. L. Holton: I would like to acknowledge my appreciation of the very kindly interest and assistance that Dr. Monkhouse has afforded me when I have been discussing with him processes that were in my mind. At this stage, in regard to the effluent treatment of the works of which I have charge, I cannot go into very definite details; but I wish to indicate something of the lines upon which we are going. At one of the works—it is a small works with a capacity up to 500,000 c.ft. per day—I have an experimental plant in which I am carrying out a series of experiments in arresting the tar immediately at the outlet of the retort house, and for that purpose I have installed a tower with 6 ft. of Raschig rings. The experiment has only been going on for a few weeks, but regularly we are obtaining, with 6 ft. of Raschig rings and 4 in. back pressure, 85 p.ct. of the total tar that is accruing from the gas. This is being followed by a second and larger series of Raschig rings in which we are going to try the washing of the gas. At the moment we are washing with anthracene, but later on I shall take advantage of the suggestion in the report to try washing with benzole and also with aniline.

The President: I think this is a very important subject, and I think we have had some very excellent contributions to the discussion. I might say that I think that a good deal may be done by controlling the temperature at the top of the retorts immediately the tar vapours meet the retort, and I am hoping that some day someone will come along and give us the results of some experiments on the deliberate cracking of the tar vapours as they leave the retorts. My own experience is that one of the chief objections to the effluent in the public sewers is on account of colour. Sometimes you get a beautiful amber colour in the effluent, and nobody seems to object, but the very next morning, just when you think you have got the conditions right for producing an excellent effluent, you find it has turned a thick brown again. That is something which I have not been able to fathom, and I wish someone would indicate some methods of dealing with effluent, even if it is only on this matter of colour. As to evaporation, unless one has some special means, I do not think the majority of us will be able to deal with more than 10 or 12 p.ct. of our effluent. I was particularly impressed with Mr. Holton's remarks; and we are very grateful to him for coming forward and telling us what he is doing. I am sure we all wish him success in the work he has undertaken.

Resinification of Phenols.

Mr. P. Parrish: I should like to congratulate the members of the Committee and their staff on the valuable report which they have presented to the Institution. There has been a good deal of fundamental work done by the Committee, but unfortunately all the processes which they have investigated do not appeal to the practical works man, inasmuch as they are likely to involve too big an expense per ton of sulphate manufactured. So far as washing gas liquor with benzole is con-

cerned, I am afraid one cannot entertain very much hope of success there, because I am certain that within the next five years there will be any amount of low-temperature tar available in this country; and one of the features of low-temperature tar is the amount of tar acids which it contains, and the recovery of that quantity of tar acids is bound to have an influence on the selling price of phenol. I have already communicated privately to Mr. Botley, the Chairman of the Effluents Committee, a method which, in my opinion, from work which has been carried out over a period of years, will ensure the purification of effluent liquor at a cost of 3s. 6d. per ton. It is the easiest matter in the world to resinify the bulk of the phenol which the effluent liquor contains, and by mere treatment in this way to ensure resinification of the phenol and of the thiocyanates and thiosulphates. It is possible in the simplest type of plant to ensure the reduction of the oxygen-absorption figure of a phenol to such a degree as will be equivalent to domestic sewage. This matter, I understand, is to be investigated; and I know from practical experience on a large scale, that the process is capable of adoption. I think it is on these lines that the gas industry will have to look for a solution to this very persistent and very embarrassing problem.

Mr. BOTLEY: There are only a few words which I propose to add, because I would like Dr. Monkhouse to reply to the points that have been raised. First of all, may I say that this meeting, from my point of view, has been worth while. You will understand that as Chairman of the Committee I frequently have information given to me which I am bound to treat in confidence; and I do so. Thus some of the matter which is given me personally cannot appear in a published report. The matter referred to by Mr. Holton is coming before his own Committee, and therefore cannot be referred to in detail now. Mr. Holton, however, has been good enough to promise that our own Committee shall have the benefit of his experience, so that it will be available for the whole of the industry; and I am very hopeful that this experience will be of great value to all of us. I am sure we shall all wish to thank Mr. Holton for having made that promise.

My friend Mr. Parrish has a process which we are investigating. It is referred to in my foreword to the report as one of the things which we are investigating, and I have great hopes of the process. I thank Mr. Parrish on behalf of the Committee for what he has said, and we shall certainly follow-up the matter.

Mr. J. MITCHELL (Nelson, Lancs.): The trouble we have experienced at Nelson in discharging our effluent into the sewers is that the sewers have become choked up. We used a plough through the sewer, and then we got into trouble with the Urban District Council for breaking the sewer. The matter became very serious, and the Borough Surveyor wanted us to construct a new sewer direct to the sewage works, but that would have cost £3500. Consequently, we treated the sewer chemically, and in that way we were able to clear the sewer for £400. I thought perhaps this experience might be valuable to others who are in a similar position.

REPLY OF DR. MONKHOUSE.

Dr. MONKHOUSE, replying to the discussion, said: It must be remembered that one of the main ways that gas-works have of getting rid of their effluent is by discharge into the sewers, and what has been done is to inquire whether it is possible to reduce, either in volume or in toxicity, the liquor which you are discharging, because in certain cases, which are on the border line, it may be possible to use the sewer satisfactorily. There has been a great deal of prejudice towards gas-works effluent by sewage authorities, but this is tending to change. The results of such work as that carried out at Cheltenham, which were published last year, have done a great deal to lighten this problem. I should like to thank Mr. Holton for the results he has mentioned with regard to the use of Raschig rings. One point in regard to them is the back-pressure thrown, 4 in. Using a Colman type of extractor at Coventry we were working on a back-pressure of 1 to 1¼ in., and we found it rather a difficult thing to work with high pressures. Owing to the limitation of the exhauster we were unable to control the temperature at the top of the retort. It is a very interesting problem; you are trying to get back to tar and liquor of the type you are getting from horizontal retorts, and this raises some very interesting questions. In regard to the colour of the effluent, you sometimes find that this colour is largely due to excess lime present in the effluent. There is an oxidation due to the absorption of oxygen from the air, which turns the effluent brown. At one works, through acidifying the effluent, it has been possible to get the change from a reddish-brown colour to a nice amber or even a pale yellow; but you do not reduce the oxygen absorption value of your effluent at all. We are hoping to investigate the process mentioned by Mr. Parrish, and are looking forward to it with great interest. With regard to the incrustation mentioned by Mr. Mitchell, he has already kindly given to the Committee the results of what he has done; but I do not think we have yet had before us another case in which there has been reduction to calcium carbonate in the sewer to anything like the extent to that obtained at Nelson.

3rd Report of the Ammonia Sub-Committee

The members of the Ammonia Sub-Committee for 1929-30 were: C. F. Botley, M.Inst.C.E. (Chairman), H. E. Bloor, B.Sc., B.Eng., E. V. Evans, H. Hollings, M.Sc., P. G. G. Moon, A. Parker, D.Sc., T. F. E. Rhead, M.Sc., E. W. Smith, C.B.E., D.Sc., F.I.C., W. W. Townsend, John Wilkinson, O.B.E., and Prof. J. W. Cobb, C.B.E., B.Sc., F.I.C. (Honorary Secretary).

GENERAL INTRODUCTION.

By the Livesey Professor (JOHN W. COBB, C.B.E., B.Sc., F.I.C.).

The Sub-Committee has completed during the past twelve months the sectional survey which it had decided to make of the possibilities of various methods used and suggested for the economic recovery of ammonia in gas-works practice.

Various additional sectional reports have been submitted and discussed by the Sub-Committee in accordance with this scheme, and as a result of its deliberations, publication is now made of two of these, one on the Feld Processes by Dr. A. Parker, and the other on the Use of Anhydrite in the Production of Ammonium Sulphate by Mr. P. Parrish. This part of its work being completed, the Sub-Committee decided that the next useful step would be to present a reasoned summary and survey of the sectional reports which should indicate their bearing on the general question of ammonia recovery as it affects the Gas Industry. The responsibility and difficulty of this task are obvious, and the thanks of the Sub-Committee are due to two of its members, Mr. H. Hollings and Dr. E. W. Smith, who have undertaken it. Their report, "By-Product Ammonia," has received the approval of the Sub-Committee and is now presented for reading, consideration, and discussion, in the hope that along with the sectional reports it will be of service to the industry.

Apart from the subject matter of the sectional reports the Sub-Committee has also had before it during the year various proposals concerning ammonia production, including that of Mr. W. Wilson, of Burton-on-Trent, for the production of ammonium bicarbonate, into which inquiry has already been instituted with the assistance of Dr. Monkhouse, Research Chemist of the Liquor Effluents Sub-Committee.

THE FELD PROCESSES FOR THE EXTRACTION OF AMMONIA AND SULPHURETTED HYDROGEN FROM COAL GAS.

By A. PARKER, D.Sc., Assoc.Inst.Gas E.

A number of processes were designed by the late Walther Feld for the purification of crude coal gas. The earlier processes aimed at removing only sulphuretted hydrogen, but the experiments carried out in this connection led to the later processes in which the object was to effect the simultaneous removal of both sulphuretted hydrogen and ammonia.

It is proposed to consider both types of process in this paper, for methods of removal of sulphuretted hydrogen

and ammonia whether separately or simultaneously have a direct bearing on the ammonia problem in that both sulphur and ammonia are required in the production of ammonium sulphate.

Process I.

In the first process to be considered the underlying principle is the oxidation of sulphuretted hydrogen by sulphur dioxide according to the reaction given in equation (1):—

$$2H_2S + SO_2 = 2H_2O + 3S \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

The sulphur dioxide was first dissolved in a tar oil which was then employed in a Feld centrifugal washer through which the crude coal gas was passed. The sulphur produced by the reaction dissolved in the oil, the temperature of which was raised by the heat developed in the reaction between the two gases. The oil was again saturated with sulphur dioxide and re-used in the washer several times until the quantity of sulphur in solution was sufficient to allow of the separation of sulphur on cooling the oil. Part of the sulphur recovered was used for the production of the sulphur dioxide required. The process was not a success as the reaction between the sulphur dioxide and sulphuretted hydrogen proceeded only slowly and difficulty was experienced in recovering the sulphur from the tar oil.

Process II.

In Feld's next process, the sulphuretted hydrogen was removed from crude coal gas by means of sulphite and thiosulphate of zinc, the zinc sulphide produced being reconverted into thiosulphate by the action of air and sulphur dioxide.

A suspension of zinc oxide in water was treated with sulphur dioxide to produce zinc sulphite which was used to wash the crude coal gas, the two reactions proceeding as shown in equations (2) and (3).

$$ZnO + SO_2 = ZnSO_3 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$
$$ZnSO_3 + 3H_2S = ZnS + 3H_2O + 3S \quad . \quad . \quad . \quad . \quad . \quad (3)$$

The suspension of zinc sulphide and sulphur in water was then submitted to the action of sulphur dioxide and air, by which the sulphide was converted into thiosulphate, equation (4).

$$ZnS + 3S + SO_2 + O = ZnS_2O_3 + 3S \quad . \quad . \quad . \quad . \quad . \quad (4)$$

The solution of zinc thiosulphate containing suspended sulphur was afterwards employed in the washer for the absorption of sulphuretted hydrogen with precipitation of zinc sulphide and sulphur according to equation (5). The mixture of zinc sulphide and sulphur in suspension was again subjected to the action of sulphur dioxide and air and the reactions indicated by equations (4) and (5) were repeated until the weight of sulphur in suspension was about 15 per cent.

$$ZnS_2O_3 + 3S + 3H_2S = ZnS + 3H_2O + 7S \quad . \quad . \quad . \quad (5)$$

The zinc sulphide was then dissolved as thiosulphate by treatment with sulphur dioxide and air, and the sulphur was removed by filtration, leaving the thiosulphate for further use in the process. The sulphur dioxide required was obtained by combustion of part of the sulphur recovered.

The process was tried on the Continent and at Hull, but was not satisfactory. Other reactions occurred in addition to those mentioned, and these gave rise to zinc polythionates which did not readily bring about the oxidation of sulphuretted hydrogen and consequently interfered with the cycle of operations.

Process III.

The observation that polythionates of iron in presence of water and ammonia decompose on heating to produce ferrous sulphate, sulphur, and sulphur dioxide, led to the development of a process in which an aqueous solution of ferrous sulphate was the initial reagent for the simultaneous removal of sulphuretted hydrogen and ammonia and the production of a solution of ammonium sulphate. The process depended on a number of reactions of which the principle may be represented by equations (6) to (9).

$$2FeSO_4 + 4NH_3 + 2H_2S = 2FeS + 2(NH_4)_2SO_4 \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$
$$2FeS + 3SO_2 = 2FeS_2O_3 + S \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$
$$2FeS_2O_3 + 4NH_3 + 2H_2S = 2FeS + 2(NH_4)_2S_2O_3 \quad . \quad . \quad . \quad . \quad . \quad (8)$$
$$2FeS + 2(NH_4)_2S_2O_3 + 3SO_2 + 2O_2 = 2FeSO_4 + 2(NH_4)_2SO_4 + 5S \quad (9)$$

Crude coal gas was first washed with a dilute solution of ferrous sulphate which gave rise to the formation of ammonium sulphate with the precipitation of ferrous sulphide, equation (6). The solution of ammonium sulphate containing black ferrous sulphide in suspension was then treated with sulphur dioxide, which resulted in the production of ferrous thiosulphate and sulphur, equation (7). The liquor, which then contained ferrous thiosulphate and ammonium sulphate in solution and sulphur in suspension, was again used for washing the crude gas, when reaction (8) occurred with the production of ferrous sulphide and ammonium thiosulphate. The liquor from this stage of the process was subjected to the action of sulphur dioxide to convert the ferrous sulphide into ferrous thiosulphate, and the processes indicated by equations (7) and (8) were repeated until the liquor contained 30 to 45 per cent. of ammonium salts. The liquor from reaction (8) was afterwards heated and oxidized by treatment with sulphur dioxide and air according to reaction (9) to produce ferrous sulphate and ammonium sulphate in solution and sulphur in suspension. The sulphur was removed by filtration, and the solution was treated with crude coal gas to convert the ferrous sulphate into ferrous sulphide and to produce a further quantity of ammonium sulphate, equation (6). The ferrous sulphide was separated by filtration, and the solution of ammonium sulphate was evaporated for the recovery of the salt.

The process was tried in an experimental plant at Königsberg and gave promise of success, but difficulties soon developed. Other reactions occurred in addition to those indicated in equations (6) to (9), and one of the side reactions gave rise to the separation of iron pyrites in the plant.

Process IV.

The difficulties experienced in the processes in which salts of zinc and of iron were employed, led Feld to make use of his observation that sulphuretted hydrogen and ammonia could simultaneously be removed from crude coal gas by means of solutions of ammonium polythionates.

In the first stage of the latest Feld process, the gas was washed with an aqueous solution containing trithionate and tetrathionate of ammonia, and the reactions which occurred may be represented by equations (10) and (11).

$$(NH_4)_2S_3O_6 + 2NH_3 + H_2S = 2(NH_4)_2S_2O_3 \quad . \quad . \quad . \quad (10)$$
$$(NH_4)_2S_4O_6 + 2NH_3 + H_2S = 2(NH_4)_2S_2O_3 + S \quad . \quad . \quad (11)$$

The spent liquor from the first stage, containing ammonium thiosulphate in solution and sulphur in suspension, was regenerated by treatment at 35° to 40° C. with sulphur dioxide to produce a solution containing polythionate as indicated in equation (12).

$$2(NH_4)_2S_2O_3 + 3SO_2 + S = 2(NH_4)_2S_4O_6 \quad . \quad . \quad . \quad . \quad (12)$$

The gas-washing and regeneration processes were repeated until the solution was saturated with ammonium polythionates, which were decomposed by boiling to produce ammonium sulphate, sulphur, and sulphur dioxide, reaction (13).

$$(NH_4)_2S_4O_6 = (NH_4)_2SO_4 + SO_2 + 2S \quad . \quad . \quad . \quad . \quad . \quad (13)$$

Sulphur dioxide from this reaction was used in the regeneration of spent liquor, and after removal of sulphur by filtration the solution of ammonium sulphate from (13) was evaporated to crystallize the salt.

In addition to the reactions given in equations (10) to (13) many other reactions occurred, and the nature and extent of these was influenced by the relative proportions of ammonia and sulphuretted hydrogen in the gas.

Two large plants for the operation of the process were erected at the "Sterkrade" and "Fröhliche Morgensonne" coke oven installations, and experiments were carried out over a period of several years. The process was not a success and was given up during 1918. It was only towards the end of the long experimental period that it was recognized that the reactions during the washing of the gas with polythionate solution were affected by carbon dioxide, which is always present in appreciable quantities in coal gas. In addition, the regeneration process pro-

ceeded slowly and necessitated the use of large regeneration vessels. The addition of arsenious acid, as suggested by Raschig, increased the velocity of the reaction during regeneration to some extent, but the acceleration was not sufficient to ensure the success of the process as a commercial proposition.

SUMMARY.

Two processes were developed by W. Feld for the simultaneous extraction of ammonia and sulphuretted hydrogen from crude coal gas and the production of ammonium sulphate. In the first the absorption of ammonia and sulphuretted hydrogen was achieved by solutions of ferrous sulphate and thiosulphate and regeneration of the solutions for further use was brought about by the action of sulphur dioxide and air, the sulphur dioxide being produced by the oxidation of sulphur recovered in the process. In the second process the ammonia and sulphuretted hydrogen were removed by a solution of ammonium polythionates, and the solution was regenerated for further use by oxidation with sulphur dioxide and sulphur.

In both processes various difficulties arose, partly owing to the development of troublesome side reactions which occurred in addition to the main reactions desired. Further, the processes appear to be too complex for satisfactory operation on a gas-works.

In any process for the simultaneous recovery of ammonia and sulphuretted hydrogen from coal gas and the production of ammonium sulphate, sulphuretted hydrogen must be oxidized to produce "SO_3" radicle to neutralize the ammonia. In the usual method of purification of coal gas, the sulphuretted hydrogen is taken up by iron oxide, and the first stage of oxidation of the sulphide to sulphur is brought about by exposure to the atmosphere. The sulphur is then further oxidized in the manufacture of sulphuric acid. One of the primary considerations in a comparison of existing practice with processes similar to those devised by Feld, therefore, is the relative cost of oxidation of sulphuretted hydrogen to the sulphate radicle, and in this respect it appears that the Feld processes do not show any indication of offering advantages.

THE USE OF ANHYDRITE (CALCIUM SULPHATE) IN THE PRODUCTION OF AMMONIUM SULPHATE.

By P. PARRISH, A.I.C., M.I.Chem.E., M.Inst.Gas E.

SUMMARY.

What is important is that an examination should be made of the process for the manufacture of ammonium sulphate where anhydrite is used in lieu of sulphuric acid in more detail than has hitherto been extended to this aspect of the subject. Statements have appeared from time to time to the effect that the bye-product ammonia problem may possibly be solved by resorting to the use of anhydrite, in lieu of sulphuric acid, in the manufacture of sulphate of ammonia. Such statements should not be accepted implicitly. Indeed, the whole position should be examined scrupulously. The number of unit processes involved in the utilization of anhydrite in the manufacture of ammonium sulphate is not generally realized. Neither is the importance of large-scale operations, nor the economics of the process, fully appreciated.

Where concentrated gas liquor is used, and sulphuric acid is the source of the SO_3 ion in the manufacture of ammonium sulphate, a gas liquor still with heat interchangers and coolers, and a saturator and equipment, are the only plant involved.

We come now to the cost of anhydrite, having regard to the unit processes involved, in contrast to the price of sulphuric acid. It is known that anhydrite containing (say) 90 p.ct. of calcium sulphate can be obtained in the neighbourhood of the mines at 12s. 6d. per ton, but delivered in London or the equivalent, it will cost 25s. per ton. How far the anhydrite process is likely to prove advantageous depends largely on the geographical situation of the ammonia works in relation to the anhydrite mines. The following estimates will doubtless prove interesting, representing as they do, a pecuniary comparison of anhydrite (*a*) under the best conditions, and (*b*) under conditions obtaining in London, as contrasted with the price of sulphuric acid.

EXAMPLE (*a*): *Estimate Based per Ton of Ammonium Sulphate Manufactured, containing 25·5 P.Ct. NH_3.*

	£	s.	d.
(*a*) 24 cwt. of anhydrite at 12s. 6d. per ton at mines, *plus* 2s. 6d. per ton carriage = 15s. per ton	0	18	0
(*b*) Grinding 24 cwt. of anhydrite at 4s. per ton	0	4	10
(*c*) Extra cost for power and labour for filtration and handling the calcium carbonate sludge	0	5	0
(*d*) Interest at 5 p.ct. and depreciation at 7½ p.ct. on extra capital cost of plant—say	0	1	0
(*e*) Extra chemical supervision	0	3	6
(*f*) Cost of treatment of flue gases for carbonatation process	0	2	6
(*g*) Water for cooling and washing precipitated calcium carbonate cake	0	2	6
	£2	0	4

Against the above, where sulphuric acid is used, one has the following charge:

	£	s.	d.
1·11 tons of 70 p.ct. acid at (say) 55s. per ton	3	1	0
Difference in favour of the anhydrite process, per ton of ammonium sulphate manufactured	1	0	8

EXAMPLE (*b*): *Estimate Based per Ton of Ammonium Sulphate Manufactured, containing 25·5 P.Ct. NH_3.*

	£	s.	d.
(*a*) 24 cwt. of anhydrite at 25s. per ton, delivered London, or equivalent	1	10	0
(*b*) This item is identical with example (*a*)	0	4	10
(*c*) " " " "	0	5	0
(*d*) " " " "	0	4	0
(*e*) " " " "	0	3	6
(*f*) " " " "	0	2	6
(*g*) " " " "	0	2	6
	£2	12	4

Against the above, where sulphuric acid is used, one has the following charge:

	£	s.	d.
1·11 tons of 70 p.ct. acid at (say) 55s. per ton	3	1	0
Difference in favour of the anhydrite process per ton of ammonium sulphate manufactured	0	8	8

The comparison afforded by the two foregoing statements is as accurate as the writer's experience will admit of. The figures show an advantage of 20s. 8d. per ton where anhydrite can be obtained favourably, and 8s. 8d. per ton where the ammonia works is situated in London, or the equivalent.

It is obvious, therefore, that the anhydrite process as an alternative to the use of sulphuric acid needs to be carefully considered. The nature of the process, however, necessitates a medium-size scale of operations, and it is the writer's view that plant to deal with *less* than 30 to 40 tons of ammonium sulphate per day would not be warranted.

Only one further comment is called for. Where the centrally situated chemical works is sufficiently large, it would, perhaps, be advisable to consider a process which involved the manufacture of di-ammonium phosphate and calcium nitrate from (*a*) concentrated gas liquor, (*b*) ground phosphate rock treated with sulphuric acid in the manufacture of phosphoric acid, and (*c*) the utilization of the precipitated calcium sulphate (which is really in a better form physically than anhydrite) in the production of ammonium sulphate.

Incidentally, the calcium carbonate produced from the latter process could be treated with nitric acid obtained by the oxidation of ammonia (Ostwald process), to yield calcium nitrate and release carbon dioxide for the carbonatation process.

One such cyclic process, possessing distinctive features, has been suggested by Dorr-Liljenroth, and it is certain that more will be heard of the process in the near future.

As far as one can ascertain from a consideration of railway rates and other related data, the radius covered by any centrally-situated chemical works treating concentrated gas liquor or ammonium sulphate solution should not be more than forty miles.

The foregoing is a portion of the contribution by Mr. Parrish to the World Power Conference—Fuel Conference, 1928, on the subject of "Some Technical and Economic Aspects of the By-Product Ammonia Recovery Problem."

Since that contribution was made, opportunity has offered to investigate certain aspects of the production of ammonium sulphate from calcium sulphate.

It was originally thought that one series of vessels might serve for carbonatating the concentrated gas liquor

and securing successive but immediate interaction of the nascent carbonates of ammonia with calcium sulphate. Trials conducted on a semi-technical scale in the plant shown in the accompanying photograph (figure 1) revealed that this was not altogether a desirable procedure. While ammonium sulphate could be obtained of satisfactory concentration, it was found that ammonium polysulphide remained at the end of the process to the extent of 1·5 to 2 per cent., and that neutralization of the filtered ammonium sulphate solution led not only to the evolution of hydrogen sulphide, but to the precipitation of free sulphur in a fine form, which rendered filtration necessary.

From several viewpoints it is eminently desirable to carbonatate in a separate vessel, specially designed for the purpose. Not only is there economy of plant, but equally, economy of time, because carbonatation and interaction can proceed simultaneously in separate suitable vessels, and in both cases provision can be made for obtaining optimum conditions for mass reaction.

The interaction is essentially one of the mass type, and its speed is a function of the concentration of the reacting substances. Since the final product is in solution and one of the reacting substances is also in solution, it follows that the concentration of this body—viz., ammonium carbonate—must reach a minimum, and thus reduce the velocity of the interaction towards the end of the process.

Unfortunately, the process is not of that order where maximum concentrations of the interacting bodies can be maintained, and the resultant product removed either intermittently or continuously.

Where an attempt was made to carbonatate and secure interaction in one vessel, 79 per cent. conversion was effected in seven hours, as is shown in Table 1.

TABLE 1.

Time, In Hours.	Per Cent. Free NH_3.	Per Cent. NH_3 as $(NH_4)_2SO_4$.	Per Cent. Conversion.
..	11·61	..	..
1	..	2·49	21·4
2	..	4·30	38·0
3	..	5·70	49·0
4	..	7·29	62·7
5	..	8·51	73·8
6	..	8·91	76·8
7	..	9·18	79·0

NOTE.—The rapid conversion during the first hour is due to the presence of carbonates in the original liquor.

On the other hand, where steps were taken to carbonatate in a separate vessel of special design, this stage of the process was carried out fairly rapidly. The conversion of 79·8 per cent. of the carbonate of ammonia to sulphate with anhydrite in a reaction vessel, representing the second stage of the process, took only 2¼ hours; in point of fact, 56·7 per cent. conversion was attained in half an hour. Table 2 elucidates the foregoing, and also reveals the diminution in the rate of reaction.

TABLE 2.

Time.	Per Cent. Free NH_3.	Per Cent. NH_3 as $(NH_4)_2SO_4$.	Per Cent. Conversion.
Hrs. Mins.			
.. ..	9·05	..	..
15	..	4·07	45·0
30	..	5·14	56·7
45	..	5·73	63·3
1 0	..	6·24	69·0
15	..	6·61	73·1
30	..	6·89	76·0
45	..	7·08	78·2
2 0	..	7·15	79·0
15	..	7·22	79·8

In the original contribution it was suggested that six reaction vessels were necessary, and that these should be arranged so as to operate either by forward or backward rotation. Subsequent work on a semi-technical scale has made clear that where the unit processes just described are carried out in one series of similar vessels, four only are necessary.

FIG. 1.

In the foregoing connection it is significant that carbonatation must proceed in specially designed apparatus until all the ammonia has been converted to ammonium bicarbonate, otherwise the ammonium sulphides and polysulphide will not be completely decomposed. Such complete decomposition is scarcely possible in vessels which are intended for the double purpose of carbonatation and interaction, and where the design must necessarily be imperfect for attaining the best results as affecting the first-named unit process.

It has been demonstrated that interaction of ammonium bicarbonate with anhydrite can be effected with only two vessels, one being in operation while the other is being discharged and recharged. The CO_2 evolved should be conducted to the carbonatation tower and utilized there.

If the carbonatating medium is of low CO_2 concentra-

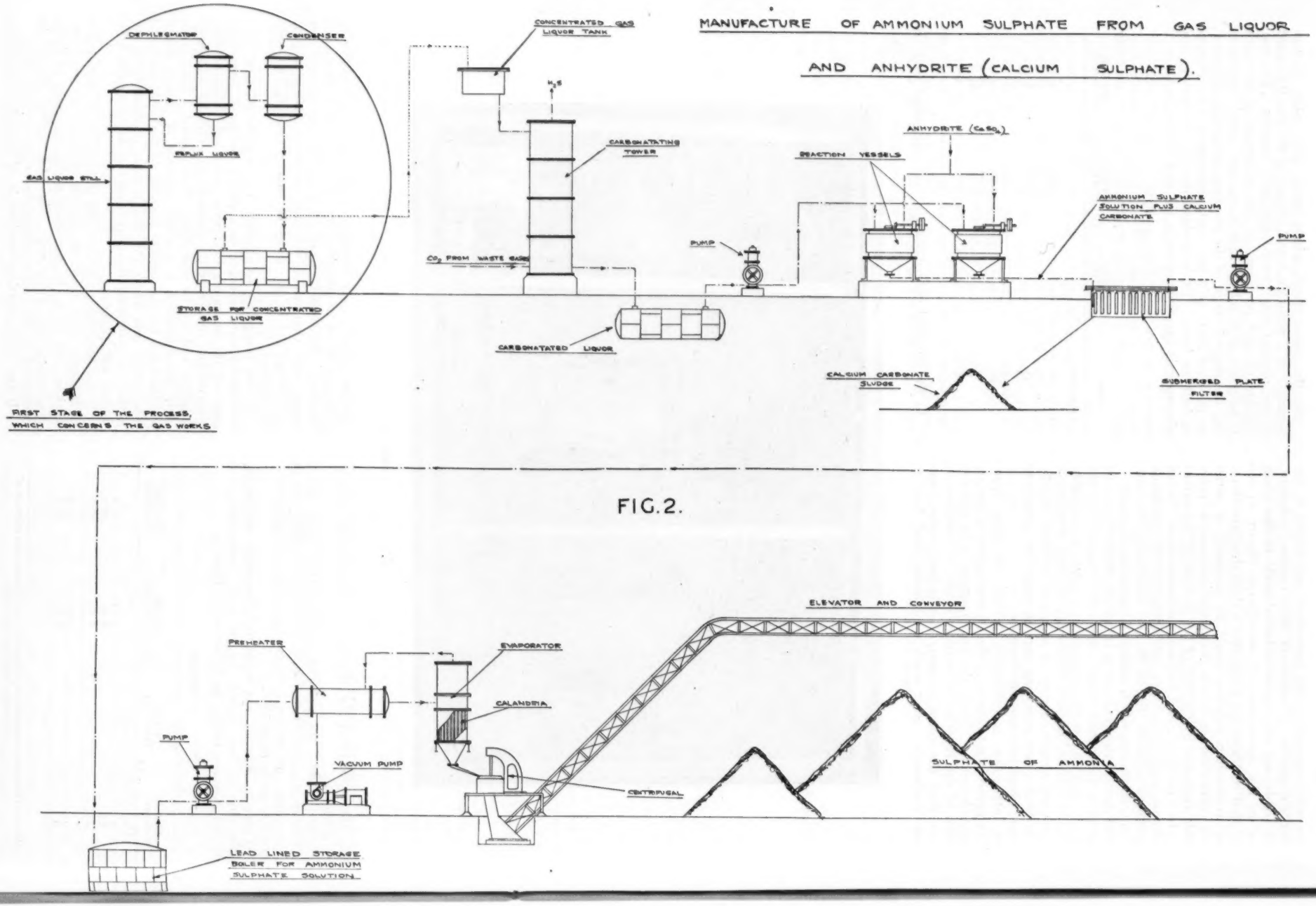

MANUFACTURE OF AMMONIUM SULPHATE FROM GAS LIQUOR
AND ANHYDRITE (CALCIUM SULPHATE).
DEPHLEGMATOR
CONDENSER
REFLUX LIQUOR
GAS LIQUOR STILL
STORAGE FOR CONCENTRATED GAS LIQUOR
FIRST STAGE OF THE PROCESS, WHICH CONCERNS THE GAS WORKS
CONCENTRATED GAS LIQUOR TANK
H_2S
CARBONATATING TOWER
CO_2 FROM WASTE GASES
CARBONATATED LIQUOR
PUMP
ANHYDRITE ($CaSO_4$)
REACTION VESSELS
AMMONIUM SULPHATE SOLUTION PLUS CALCIUM CARBONATE
PUMP
CALCIUM CARBONATE SLUDGE
SUBMERGED PLATE FILTER
ELEVATOR AND CONVEYOR
PREHEATER
EVAPORATOR
CALANDRIA
PUMP
VACUUM PUMP
CENTRIFUGAL
SULPHATE OF AMMONIA
LEAD LINED STORAGE BOILER FOR AMMONIUM SULPHATE SOLUTION

FIG. 2.

tion, the hydrogen-sulphide concentration in the effluent gases would be such that treatment in a Claus plant may be either impossible or uneconomical, and recourse must be had to an oxide of iron purifier. If, on the other hand, CO_2 of relatively high concentration is available (and this may involve the absorption of CO_2 from flue gases of weak concentration in sodium carbonate solution, and the subsequent decomposition of the bicarbonate so formed necessitating additional plant for this purpose), then the hydrogen sulphide evolved can be recovered as sulphur by the Claus process. It is believed that the latter can be improved upon appreciably, both as regards economy of plant and efficiency of operation, as contrasted with former design and practice.

Where the dual function of carbonatation and interaction is intended the use of flue gases of low CO_2 concentration demands plant of unwieldy dimensions if violent agitation and entrainment are to be avoided.

Where provision is made for carbonatation and interaction proceeding in the same vessel, it will be found that there is little need for cooling water, since the rate of reaction is slow, and an appreciable volume of inert gases is passing, which absorbs the heat of reaction.

On the other hand, where vessels are assigned for interaction of anhydrite with ammonium bicarbonate, water cooling is essential, as the temperature rise due to the exothermic nature of the reaction is considerable.

In the original contribution it was suggested that under certain conditions of operation a 20 per cent. ammonium sulphate solution was the highest concentration obtainable without interference from calcium carbonate.

Subsequent repeated trials have disclosed that there is no difficulty in obtaining concentrations of ammonium sulphate of 40 per cent., given anhydrite of suitable chemical composition and physical characteristics. This is about the highest concentration that can be obtained short of crystallization.

Semi-technical scale operation has revealed that with Gotham anhydrite the separation of ammonium sulphate solution from the precipitated calcium carbonate presents little difficulty. It is a fairly simple operation, preferably conducted in a submerged type of filter.

The efficiency of the conversion of the calcium sulphate content of the anhydrite to calcium carbonate is of the order of 92 per cent., but this is largely a function of the particle size of the anhydrite. Where relatively coarse material is employed there is a tendency for the particles to become coated with calcium carbonate, and thus the efficiency of the conversion is retarded. All the anhydrite should pass a 100-mesh screen.

Further trial working has made evident that it is impracticable to carry the interaction to completion. Invariably about 1·0 to 1·5 per cent. of ammonia as ammonium bicarbonate remains, and it is necessary to neutralize the latter with sulphuric acid in an external vessel if this ammonia is to be recovered.

Additional experience of the evaporation of ammonium sulphate solution confirms the soundness of the observations made in the original contribution on this aspect, and suggests that a homogeneously lead-lined steel evaporator is to be preferred for this work, where neutral or slightly alkaline solutions are to be treated. Considerable difficulty has been experienced in the choice of suitable metals for the construction of the evaporators for the purpose in question. Fundamentally, the problem resolves itself into this. If the ammonium sulphate solution is made slightly acid, copper can be used as the metal for the construction of the calandria of the evaporator and the preheater, but it will be appreciated that an acid-containing sulphate of ammonia will be discharged to the centrifugal, and this will need to be neutralized subsequently.

On the other hand, if it is desired to use neutral or slightly alkaline solution, with a view to producing neutral ammonium sulphate direct, without resorting to any neutralizing process, then it is certain that a homogeneously lead-lined steel evaporator is to be recommended.

From the viewpoint of heat transmission, the following data in the above connection are of interest :—

The thermal conductivities (λ) of copper, steel, and lead are respectively 220, 25, and 20 B.Th.U.'s per square foot per foot thick per degree Fahrenheit per hour. This factor, however, is a comparatively small one in the efficiency of heat transfer through a metal wall, the greatest resistance being due to the stagnant film on either side of the metal.

Assuming (1) copper tubes $\frac{1}{8}$ in. thick,
,, (2) steel tubes $\frac{1}{8}$ in. thick, and
,, (3) steel tubes $\frac{1}{8}$ in. thick, lined with $\frac{1}{8}$ in. thick lead,

the following calculations show the extent to which the substitution of these tubes will affect the heat transfer :—

$$Q = \frac{1}{\frac{L}{\lambda_1} + \frac{L_2}{\lambda_2} + \frac{L_3}{\lambda_3}}$$

where Q = heat transferred per 1° Fahr.
L = length of path,
λ = thermal conductivity.
$L = \frac{1}{8}$ in. = 0·01 foot (approximately).

$\frac{L_2}{\lambda_2}$ = for copper, $\frac{0{\cdot}01}{220} = 0{\cdot}00C045$

For steel, $\frac{0{\cdot}01}{25} = 0{\cdot}0004$

For steel and lead, $\frac{0{\cdot}01}{25} + \frac{0{\cdot}01}{20} = 0{\cdot}009$

$\frac{L_1}{\lambda_1}$ and $\frac{L_2}{\lambda_2}$ will not vary, and may be taken as 0·002 in each case.

Then :

(1) $\frac{1}{0{\cdot}002 + 0{\cdot}000045 + 0{\cdot}002} = 247$

(2) $\frac{1}{0{\cdot}002 + 0{\cdot}0004 + 0{\cdot}002} = 229$

(3) $\frac{1}{0{\cdot}002 + 0{\cdot}0009 + 0{\cdot}002} = 204$

The heating surface required for a given evaporation will vary inversely as the above figures, and will be as follows, taking copper as unity :—

Copper	1·00
Steel	1·12
Lead	1·21

Thus, it will be appreciated that where a lead-lined shell and lead-lined tubes are necessitated in the construction of a calandria and preheater, approximately 25 per cent. more heating surface will be required as contrasted with a calandria made of a copper shell and copper tubes.

No useful purpose would be served by taking advantage of the flue gases available at small works and carbonating the gas liquor there, and subsequently distilling the carbonatated liquor and supplying concentrated ammonium bicarbonate solution, to a central chemical works. The operations involved are of a different order from what the gas engineer of small and medium sized works is normally accustomed to, and for the most part are outside the ambit of normal gas-works equipment and practice.

In order to allow gas managers and engineers to visualize the type of plant involved for the production of ammonium sulphate from anhydrite, a diagrammatic sketch has been prepared (figure 2), which shows clearly the sequence of the various unit processes, and isolates by a ring the part which the gas-works would play in the production of concentrated gas liquor, which represents the first stage of the process under review.

That the production of ammonium sulphate from anhydrite may be regarded as a conventional chemical works operation is abundantly confirmed by the trials which have been conducted since the original contribution was made. Indeed, subsequent investigation has revealed that in certain respects the process can be simplified, that a higher concentration of ammonium sulphate solution, up to 40 per cent., is possible, that filtration difficulties are not likely to arise with the Gotham quality of anhydrite, and these advantages must inevitably be reflected in reduced operating costs, below what were originally foreshadowed in the contribution which forms the preface of this thesis.

BY-PRODUCT AMMONIA.

By H. Hollings, M.Sc., M.Inst.Gas E., and E. W. Smith, C.B.E., D.Sc., F.I.C., M.Inst.Gas E.

It is common knowledge that the value of ammonia on gas-works has depreciated considerably in recent years due, in part, to a fall in price of sulphate of ammonia, and in part to an increase in the cost of conversion of gas

liquor into sulphate. The Ammonia Sub-Committee of the Institution have sought for some means capable of immediate commercial application for increasing the net value of ammonia on gas-works. If there is any such means available, then it should be applied irrespective of whether ammonia recovery is now more or less remunerative than formerly, and irrespective of whether the removal of ammonia is a profitable adjunct to gas making or a necessary step in the purification of gas which entails a charge upon the gas making process.

In fact, the net value of ammonia has now fallen to such a point that under existing circumstances at many works it no longer meets the cost of removal. Notwithstanding this unfavourable economic result of ammonia removal the process must be continued in order to obtain a gas sufficiently pure for general distribution. Furthermore, the surplus water must be removed from the gas, and the disposal of this water, together with the impurities with which it is associated, is regarded as part of the ammonia removal problem.

The quantity of ammonia liquor produced at gas works in Great Britain is equivalent to about 150,000 tons of sulphate of ammonia per annum. It appears to us important to keep this quantity clearly in mind, because if it is proposed to manufacture any ammonia product other than the sulphate which is most generally manufactured to-day, some readily available market must be found for the new product in bulk. There may be special circumstances under which a particular undertaking may find it advantageous to make a relatively small quantity of other ammonia products, and to develop a specialized business. Any such special case, however, falls outside the field of our present investigation notwithstanding any special technical interest it may possess, unless there is a reasonable prospect of the market for the final product being within a few years large enough to absorb a quantity of ammonia which represents a large proportion of the total with which we are concerned, and which is at least comparable with the production of ammonia by undertakings not owning sulphuric acid plants.

It does not appear to us that so large a quantity of ammonia as the whole industry is compelled to dispose of can be placed in any market other than the Fertilizer Market. Thus we confine our enquiry to the conversion of by-product ammonia into a marketable fertilizer or alternatively to its destruction if this proves more economical.

It was shown in the second report of the Ammonia Sub-Committee that the use of ammonia in the gas-works as an agent for the removal of hydrogen sulphide from crude gas was not likely to contribute towards the solution of the economic problem under consideration.

Many of the proposals which have come before the Committee are of such a character that while they may be developed into processes capable of commercial application some years hence, and while they possess features of novelty and ingenuity, they offer no reasonable prospect of providing an immediate economic solution of the problem before us. They represent speculative investigations such as, in our opinion, cannot be conducted appropriately by research chemists working under the direction of a Committee of this Institution. Rather should such processes be developed to the further stage at which at least some of the uncertainties surrounding them can be eliminated by the private enterprise of inventors and of individual gas undertakings or commercial concerns.

The Burkheiser Process, the Feld Process, the Koppers C.A.S. Process, and Professor Cobb's Zinc Process for the extraction of ammonia and hydrogen sulphide from gas have been considered in some detail, and rejected as means for improving the economic position of ammonia in the Gas Industry.

Several proposals which have been made for the fixation of ammonia as phosphate demand further consideration because of the possible future demand for a fertilizer of this type. One process (B.P. 282927) is under investigation by the Gas Light and Coke Company, but it has not yet reached a stage at which, in our opinion, it offers a solution of our problem.

In view of the extensive adoption of the semi-direct process of ammonia recovery in the Coke Oven Industry, it is perhaps natural that many should be led to a favourable consideration of the adoption of direct or semi-direct processes in the Gas Industry.

We are of the opinion that in works carbonizing more than 300 tons of coal a day, the application of the direct and the semi-direct processes is worthy of further examination. In the event of either process being adopted, the chief disadvantage would be that existing condensing and recovery plant would in the main have to be scrapped, and a completely new type of plant, involving fresh expenditure would have to be adopted.

Where effluent troubles are serious the cost of a more efficient extraction of tar from the hot gas, which would be necessary in either case, should not be charged against ammonia recovery, and if the direct process were adopted the recovery of phenols from the subsequent condensates of ammonia free liquor might be made to pay.

It must not be overlooked that these processes are limited to the production of sulphate of ammonia.

We are still of the opinion that in the immediate future there is little likelihood of any drastic change in present practice being adopted with economic success. We do consider, however, that considerable economies may be effected in many cases by the patient and systematic application of sound chemical engineering principles to the existing indirect process of ammonia recovery. This line of development was explained in some detail in the first report of the Ammonia Committee. It was shown that savings may be effected by eliminating the use of water in ammonia washers, and avoiding the dilution of liquor which results from the use of steam for the removal of naphthalene deposits, and from the inefficient decomposition of steam admitted to retorts. The method of replacing water in washers by dilute liquor was explained, but, as may be appreciated by reference to the paper presented to the Institution in 1928 by H. Hollings, this was based upon the use of liquor of relatively high carbon dioxide content derived from vertical retort gas. The virgin liquor condensed from horizontal retort gas contains less carbon dioxide. It may, in fact, contain caustic ammonia, although it does not follow that the final mixed liquor is of this character. Because of the deficiency of carbon dioxide the virgin liquor obtained from horizontal retort gas by the method of fractional condensation previously described is a less efficient washing medium than that obtained from vertical retort gas.

This inferiority of certain liquors may be rectified by one of several methods under investigation by the Gas Light and Coke Company, and described in the Appendix.

We have already referred to the possible advantage of the destruction of ammonia in certain extreme cases.

We have noted the circular issued by the British Sulphate of Ammonia Federation entitled "Disposal of By-Product Ammonia Liquor." This may have the effect of discouraging the production of sulphate of ammonia on coke ovens and gas-works. We are of the opinion that there is no justification for such a general conclusion. There may be special reasons for the publication of the Billingham experience which do not apply in other cases. In this connection the methods of liquor treatment under investigation by the Gas Light and Coke Company, and also described in the Appendix, appear worthy of consideration.

In the selection of ammoniacal liquor for direct application to the land as a fertilizer, it is possible also that some advantage may be gained by carrying out the condensation in two stages.

It is sometimes erroneously supposed that because the manufacture of sulphate of ammonia represents a net loss, then it is advantageous to have a low yield of ammonia from the gas-works. If the low yield was accompanied by a correspondingly small bulk of virgin liquor, it might be advantageous, but more generally it is the result of the excessive decomposition of ammonia, its loss by evaporation from tanks, &c., and its slip past washers. A fall in the yield of ammonia is usually accompanied by a decrease in the strength of liquor. This often results in a still greater loss being incurred in the manufacture of sulphate of ammonia because the same bulk of liquor has to be handled and distilled, and the same amount of lime has to be used for a decreased production of salt. It would

only pay to lose ammonia by evaporation without evaporation of water if the cost of acid delivered to the sulphate plant was about the same as the net price of sulphate at the plant.

In any consideration of the costs of any of the present processes of manufacturing of sulphate of ammonia, it is obvious that the closest attention should be paid to the cost of sulphuric acid. It appears to us that this cost cannot be considered by the Gas Industry without reference to the price obtained for spent oxide. Obviously, if high prices are obtained from the acid manufacturer for the spent oxide which he uses as the raw material for sulphuric acid, it must be anticipated that there will be a correspondingly high value placed upon the acid. Thus, in reality, the cost of sulphate of ammonia manufacture is bound up with the cost of removal of hydrogen sulphide from gas.

From such information as we have been able to consult, it would appear that during the past twenty years the average price of sulphuric acid has advanced from 28s. per ton to 55s. per ton (70 per cent. basis). At the same time, it would appear that the price received for spent oxide has advanced from an average of 3·0d. per unit to 5·5d. per unit. It has been shown that where a gas-works is situated away from a sulphate of ammonia plant, the transport of liquor represents a serious item in the costs of sulphate. Furthermore, it is generally agreed that on small plants working intermittently, the costs of sulphate are inevitably higher than on larger plants. Thus we have been led to give consideration to the process of concentrating ammoniacal liquor to give a crude liquor of about 15 per cent. strength for conversion to sulphate. In some cases it may be arranged that the concentration plant shall operate continuously with the part time attention of one operator. For a study of the economics of this process, it is necessary to know in considerable detail the various costs of operating a liquor still and a sulphate saturator. Unfortunately, such information has not been available to the Committee, and we are of the opinion that more attention might usefully be given to this matter by those situated in likely districts, as it would appear that with centralized sulphate plants the local production of concentrated liquor might pay.

At the time of writing this paper a process of separation of ammonium bicarbonate from gas is under investigation on behalf of the Ammonia Sub-Committee. Subject to the results of this investigation, it appears possible that under certain circumstances this may prove to be an attractive alternative to the usual process of liquor concentration. In any case it eliminates the use of water in the recovery of ammonia. It has been proposed to distil the virgin liquor produced in the condensers as in the semi-direct process of ammonia recovery. This indicates the possibility of obtaining the whole of the ammonia in the form of solid ammonium bicarbonate in which form it should be particularly suitable for transport from an isolated gas-works to a central chemical works for conversion to sulphate.

Owing to the circumstance that calcium sulphate is used instead of sulphuric acid in the production of very large quantities of synthetic ammonium sulphate, the possibility of some such process being adopted in gas-works has naturally attracted attention. The view which has been presented to the Ammonia Committee upon this process is that it is essentially one for a central chemical works, taking concentrated liquor from a gas-works. We accept this view, and regard it as an additional argument for a further study of the economics of liquor concentration.

Furthermore, we regard the process of manufacture of ammonium bicarbonate as being in reality a process of ammonia concentration which if in itself economically sound would provide a raw material for interaction with calcium sulphate which would be preferable to concentrated ammoniacal liquor.

Summary.

As we were requested by the Ammonia Sub-Committee to make a general review of the present status of by-product ammonia, we set out the conclusions of our review below. In doing so we wish to make full acknowledgment of the information and experience placed at our disposal by members of the Committee.

1. At the present time we cannot indicate any new research upon the subject of ammonia which the Institution can initiate with any reasonable prospect of economic advantage. It is desirable, however, that individual gas undertakings should continue to develop schemes and processes that may arise.
2. The Committee should examine any new process and keep in the closest touch with all developments. For this purpose it may with advantage arrange such brief investigations as are necessary to check claims respecting new processes.
3. In most gas-works improvements in condensation and distillation conditions along the lines indicated represent the most useful work which may be taken in hand immediately.
4. Consideration should be given to the organization of district co-operative schemes for the treatment of concentrated liquor.
5. Consideration should be given to the possibility of making the gas industry self-supporting in respect of sulphuric acid.

Appendix.

Memorandum upon Experiments in Progress in the Laboratories and Works of the Gas Light and Coke Company.

Since the First Report of the Ammonia Sub-Committee was prepared in 1929 progress has been made in the investigations of the Gas Light and Coke Company in one or two directions. The data concerning the vapour pressure of ammoniacal liquor which were presented to the Institution in 1928 and which formed the basis of the suggestion relative to fractional condensation in the First Report, relate only to liquor produced from gas containing 3·5 per cent. of carbon dioxide. This limitation was made quite clear in the first instance, but further work has shown that a reduction in the carbon dioxide concentration from 3·5 per cent. to (say) 1·5 per cent., as in the case of horizontal retort gas has had a greater effect in increasing the vapour pressure of the liquor than was anticipated two years ago. These observations led to the development of a process of treating ammoniacal liquor with a small quantity of carbon dioxide prior to its use in the ammonia washer (B.P. 334619). To obtain the necessary carbon dioxide, a small quantity of waste furnace gas may be conducted to a small scrubber near the ammonia washers or the carbon dioxide which is removed from the gas in the Petit Purification process may be employed.

A method of carbonating the liquor which avoids the introduction of carbon dioxide from any external source consists in a modification of the usual direction of liquor flow through a horizontal rotary washer. If the dilute liquor which it is proposed to use for washing the gas is fed into the third bay of the washer (counting from the gas outlet end) it will not normally remove any ammonia from the gas. It will, however, absorb carbon dioxide, after which it will remove ammonia more efficiently. Thus the carbonated liquor is allowed to flow through the second bay into the first, and in this first bay it performs its normal function of ammonia removal. From the first bay the liquor flows to the fourth bay and then to the subsequent bays in the usual sequence.

It has been found also that under certain circumstances advantageous results may be obtained if the ammoniacal liquor or a part of it obtained by fractional condensation is distilled in a still heated externally or by means of steam coils so as to produce a relatively small volume of distillate containing most of the free ammonia, which, after cooling, is run to the loading tank or to the sulphate plant. The residue in the still is a relatively large proportion of the original liquor, and after cooling it is used as a washing medium (B.P. Application 29292/30).

It is preferable to segregate the liquor derived from the hydraulic mains and the foul gas mains prior to the condensers and dispose of it otherwise than by treatment in the still so as to minimize corrosion and other troubles

resulting from the contact of ammonium chloride and other salts with steam coils in the still.

From time to time various suggestions have been made relative to the use of ammoniacal liquor for coke quenching and to the discharge of it without treatment into waterways. The difficulties created by either of these processes might be mitigated if a process of fractional condensation was carried out, and if only the weak liquor from the condensation stage immediately following the retort house foul gas mains was used or disposed of in the manner suggested. There would then be available for making sulphate a much smaller bulk of liquor containing most of, but not all, the original ammonia. Experiments upon the quenching of coke in the manner indicated are proceeding.

A further means of disposal of the very weak liquor obtainable either by fractional condensation or by treatment in a still as described above which is under consideration consists in using it for generating steam for admission to the gas producers of the retort settings. Obviously this means is applicable to any ammoniacal liquor, but the wastage of ammonia may be minimized by selection or pre-treatment of the liquor as indicated above. The quantity of water evaporated on the bars or in the pans of producers in gas-works appears to be between 10 and 20 gallons per ton of coal carbonized. This quantity of weak ammoniacal liquor may be obtained conveniently by either of the two processes indicated above, and leave a correspondingly reduced bulk of stronger liquor for the manufacture of sulphate of ammonia.

It will be appreciated that the means of disposal indicated in this memorandum may be particularly advantageous in respect of the unusually dilute liquors which result from the low-temperature carbonization of coal.

An Amalgamation.

The President: I might inform you that the two Committees, the Liquor Effluents Committee and the Ammonia Committee, will henceforth be amalgamated. There will be one Committee only dealing with the two matters.

DISCUSSION.

The President: As a good many of the experiments have been carried out on Mr. Wilson's works, we shall be very glad to hear from him on the matter.

Mr. W. Wilson (Burton-on-Trent): At the outset I should like to say that I am only one of the rank and file, and as such I have been trying in my own small way to relieve the situation in my own undertaking. So far as the return from the manufacture of sulphate of ammonia is concerned, I do not want to say anything at all to-day, because I hope that the small plant I have been working with will be converted to a full-scale plant working on the whole of my gas production very shortly, and, therefore, later on I shall be pleased to come before you and give you results of what we have been doing at Burton-on-Trent on a working scale. Briefly, I might outline our investigations and what we are leading up to. In the first place we were in the same position as you all are of getting nothing for our ammonia. We have for years been working concentrated ammoniacal liquor with about 14½ p.ct. ammonia content, and this is sold on a month-to-month basis price, arrived at from the average return from sulphate of ammonia as kept by the Sulphate of Ammonia Federation; and you all know what that has been recently. Therefore, I thought I would wipe my brain clear altogether, and forget all about the Feld fancy process for obtaining H_2S with ammonia and making sulphate direct, and see what salts of ammonia could be made and how they could be made. It was apparent to me immediately that we had available in our gas more than sufficient carbonic acid to neutralize all the ammonia. As a matter of fact, some years ago I did accidentally make ammonium bicarbonate, but I did not realize what I had done and what I had seen; but when the pence get few in the pocket, and we are suffering from reduced income—I do not know whether it affects you in the South as much as it does a Scotsman—something has to be done. I decided that I would put my brains in steep and see what we could do in the way of repeating what I had accidentally done very many years ago.

The problem was how to get carbonic acid gas and ammonia together; and it really is very simple. You have only to look at the syphon of soda on your dining room sideboard to understand that there is as much CO_2 in solution as you want. I simply put a small compressor on to about 10 p.ct. of my gas stream, and compressed the foul gas into a small tower or saturator consisting of a 24-in. 12-ft. length of cast-iron pipe up on end. The first thing that happened was that we got no ammonia gas passing on the outlet, showing that, once through the bath, all the ammonia was being absorbed. It was being seized by the carbonic acid, and in about three or four days we got the bath up to a concentration point of salt formation. Since then we have been carrying on the investigations; our biggest trouble has been to get rid of the tar; and that is a matter which has been worrying many other people recently. I thank Dr. Monkhouse for many valuable hints in regard to this. Eventually, however, we were able to get the gas sufficiently tar-free before it entered the compressors, so that we got a fairly clean gas. Then, after compression, the gas has to be cooled. During the process of cooling a certain amount of light oils come out. If these are not taken out they go forward and discolour the salt; which is 99·9 p.ct. pure and as white as any piece of paper in this room.

Cost of Compression.

The only thing against the process, in my opinion, is the cost of compression; and it is rather a big step for anyone without a great deal of courage to consider compressing all one's gas. Some of us are compressing considerable percentages of clean gas and sending it out for distribution purposes, but it is a big step to compress all the foul gas. However, I am not a bit afraid of it; and it is only a question of substituting a reliable compressor in place of the present exhausters and pushing the compressed gas through one bath, or at most two baths, of water. The solution becomes saturated, and you get the salt salting out. The washed liquor coming from the hydraulic main and condenser has to be run through a still. It has been suggested to me by Mr. Botley that such a still might run continuously—*i.e.*, a steady flow of virgin liquor might be automatically separated from the tar and run steadily through a still heated by exhaust steam. This would effect considerable savings, and the gaseous products from this still have to be put back into the main gas stream, so that one compressing does for the total volume of ammonia in the gas. When it comes down to tin tacks, what do we find? We find that, if we are making 20 lbs. of sulphate per ton of coal, we can make 34 lbs. of bicarbonate. That is a simple chemical equation. You can make about one ton of bicarbonate from every 65 tons of coal. You have to compress in the region of one million c.ft. of gas to get one ton of bicarbonate. I was very pleased during the last week to get confirmation of my own experiments with regard to the cost of compression, because that is the only serious item. You get ammonia for nothing, CO_2 for nothing, and your wages will be practically the same as if you are making sulphate. Then comes the difference between the cost of compression and the cost of acid for making sulphate. I put it to probably the biggest compression experts in the world as to what would be the cost of compressing this volume of gas under the conditions which we have at Burton-on-Trent—which are free water out of the river Trent, and fuel consisting of coke at 2s. 6d. per ton—and these people have written me to say that the average consumption would be 3 tons of that fuel per ton of salt (*i.e.*, 7s. 6d.). When you allow your brain to dream about these things, you can see the enormous possibilities. But the fact is that to-day ammonium bicarbonate stands at a steady price of about £18 per ton; and if we were to make it the price would come down. However, I do not think the price would come down to one at which anyone would make a loss. I do not see how that is possible, because on my evidence it can comfortably be made well under £3 per ton, and there are many outlets for it. I do not know whether our friends at Billingham would consider buying all that the gas industry can make; but I think it would probably be cheaper than that they are making themselves to-day. This, however, is quite by the way.

New Process for Making Sulphuric Acid.

Mr. Wilton: I would not have cared to express any of my views to your meeting from a strict point of etiquette, only that a very important fact has just recently become known to me which may have an important bearing upon your deliberations and actions after hearing the very interesting data given by Mr. Hollings and Mr. Parrish. You have practically unanimously written down the ammonia you recover to zero value, owing primarily to the cost of acid. My Company has now developed, or is developing, a process which has passed the experimental stage, and is being built on a large scale now in the North for the recovery of SO_2 from flue gases. The SO_2 will be recovered in such a form that it can at least be utilized for Mr. Parrish's proposal for the manufacture of sulphate of ammonia, or in such a form that sulphuric acid can be easily produced from that material, and probably the cost of that sulphuric acid as a result of this process will be reduced very considerably, sufficient to alter the whole aspect of sulphate of ammonia production.

The President: This is a very encouraging statement from Mr. Wilton, as we are looking forward to the time when we shall be able to make a little profit on sulphate of ammonia again. A great deal has been done in the development of the manufacture of sulphate of ammonia when you consider the

quality of the salt produced to-day by gas-works as compared with the quality 10 or 12 years ago. It will be agreed that considerable progress has been made, but we are still faced with the bugbear of the cost of acid, and I shall look forward with very great interest to seeing the development alluded to by Mr. Wilton.

Ammonia Scrubbing from Horizontal Retort Gas.

Col. W. M. Carr: I would like to make some remarks on Section 4 of the Report on Bye-Product Ammonia by Mr. Hollings and Dr. Smith. The authors, in considering the savings that may be effected by eliminating the use of water in ammonia washers, previously referred to in Mr. Hollings' paper, "Some Applications of Chemistry in Gas Making," presented to the Institution in 1928, say that, "because of the deficiency of carbon dioxide, the virgin liquor obtained from horizontal retort gas by the method of fractional condensation is a less efficient washing medium than that obtained from vertical retort gas."

I hope that this statement will not create a general impression that ammonia cannot be efficiently and effectively scrubbed from horizontal retort gas by the use of cool virgin liquor of low free ammonia content. At Stretford Gas-Works, the whole of the straight coal gas is produced in horizontal retorts, and no water is used for the extraction of ammonia, nor is any difficulty experienced in obtaining complete extraction, leaving an ammonia content at the outlet of the washer of from 3 to 5 grains per 100 c.ft.—the desired quantity to keep the purifiers alkaline.

It is true that the Stretford Plant lent itself to the adoption of fixed ammonia washing in that the retorts are equipped with Congdon standpipes. The liquor flowing to the seal pots from the standpipes has a temperature of 170°-185° F. maximum, and leaves the separating tanks for re-circulation at approximately 135° F. The free ammonia content of this liquor varies from 0·65 to 0·9 oz. strength.

The procedure at Stretford is based on the suggestions put forward in Mr. Hollings' paper—that is, liquor is taken at the outlet of the Congdon circulating pumps, and is cooled in a suitable water cooler of the type that is commonly in use in connection with dry gas process, and cooled to a temperature of 60°-62° F. maximum.

The gas passes through primary water cooled condensers in which it is reduced to approximately 85° F.; after the exhausters the gas passes through a secondary water-tube condenser, and is cooled to 60° F. The free ammonia washing liquor, and gas, entering the D. & L. washer, are, therefore, both at approximately the same temperature—*i.e.*, 60° F.

In practice, the process has proved entirely successful, and it has been possible to produce a gas liquor averaging 14 ozs. strength as compared with 9-10 ozs. strength, without adding water for final scrubbing. Practically all the coals used consist of washed slacks and nuts with an average moisture content of from 5 to 6 p.ct. If dry fuels were used, it is estimated that it would be possible to maintain a liquor strength of from 16 to 17 oz.

Following the question of Mr. Hollings as to the CO_2 content of the gas, which for straight coal gas was given as 1·5 p.ct. average, the following information is sent in as a written contribution:

During the past year, the practice has been followed at Stretford of diluting the straight coal gas from the horizontal retorts with producer gas to give the desired calorific value of 500 B.Th.U. per c.ft., and the average CO_2 content of the mixed gas is 2·8 p.ct. (in unpurified gas) at inlet of scrubber. It is the practice, at the present moment, to circulate a small amount of cooled fixed ammonia liquor over the secondary water-cooled condenser, principally for the purpose of keeping it clean. A considerable amount of ammonia is, however, removed by this liquor in the secondary condenser prior to the final washing in the D. & L. washer.

The following figures show average strengths of liquor at the various points in the system under summer working conditions with washed fuels, the average moisture content of which is 5·7 p.ct.:

—	Oz. Strength Total Fixed and Free NH_3.	Amount of Free NH_3 Content, Oz.
Congdon standpipe separating tanks	7·0	0·623
Outlet of secondary condenser	12·0	5·90
Outlet of final D. & L. washer	14·0	6·23
Average of finished liquor to loading tank	13·78	6·23
		Grains per 100 C.Ft.
NH_3 content of gas—		
Inlet to secondary condensers	..	211·2
Inlet to D. & L. washer	..	118·81
Outlet of D. & L. washer	..	4·99

Mr. P. Parrish: The report which has been prepared by Mr. Hollings and Dr. Smith, on "Bye-Product Ammonia," is a statesmanlike summary of the position; it merits the most careful survey and discussion, as it constitutes, in my judgment, an expression of consummate wisdom. Curiously enough, the essential summarized findings were foreshadowed almost six years ago, in my Applied Chemistry Report, "Acids, Alkalies, and Salts" section, in 1925, in which I made the following observations anent the bye-product ammonia situation:

> The position which has arisen in the matter of gas liquor at many of the smaller gas-works, due to the operation of inexorable circumstances, must be met. Immediate action is necessary. To hope for anything approaching pre-war conditions is to "sigh for the moon."
>
> Co-operative schemes must be developed. The collection of crude liquor, preferably in a concentrated form, so as to reduce the incidence of carriage charges to a minimum, must be arranged. Such concentrated gas liquor must be treated at centrally situated chemical works equipped with modern and approved type of plant, so arranged as to be capable of manufacturing any ammonium compound at will, according to market conditions. The geographical situation of such chemical works must be carefully considered.

It is to be deprecated that the gas industry has not acted sooner in this matter, as it is certain that something of the order of half a million pounds per year is now being lost, and this may well have been avoided had there been prompt and combined action four years ago. I heartily concur in the views expressed, that most gas-works must seek to introduce improvements in condensation and distillation. It is certain that if attention be devoted to these aspects the economic results will be fully justified.

Concentrated Liquor Plants.

As regards the design and operation of concentrated gas liquor plants, it is important that improvements be effected. I recently had occasion to erect plant on behalf of my Company for the manufacture of concentrated gas liquor, and with special attention to the details of design it has been possible to evolve a plant which is peculiarly foolproof. Indeed, so simple has the operation been rendered, that it is possible to work the plant without labour, by adopting a series of sensitive temperature and pressure regulators at four cardinal points, which admit of the plant being operated automatically. If any hitch arises it is located to four points, and these slight defects can be registered on a board by a series of distinctive lights, which enables the exhauster attendant to rectify any defect quite readily. The worst that can happen in the event of the exhauster attendant not being available at the time, is that the plant would cease to operate automatically. Its working can, however, be readily re-established by the operation of a very simple device from the exhauster room. When it is remembered that the cost of labour in the production of concentrated gas liquor is something of the order of 30 p.ct., a plant possessing these features is obviously a distinct advantage.

It is impossible to adapt most of the existing sulphate of ammonia plants to operate in the production of concentrated gas liquor, as many of them are unnecessarily small, and some are not designed to ensure economy of steam consumption. Provided that a plant is capable of dealing with peak-load requirements, the primary factor governing the selection of an economic unit involves a correlation of labour costs per ton of product manufactured in relation to the charges per ton in respect of depreciation and interest on capital. The acuteness of the bye-product ammonia problem demands that efficient plant for the production of concentrated gas liquor should be erected.

Sulphuric Acid Supply.

As regards the recommendation that the gas industry should be self-supporting in respect of sulphuric acid, it is necessary to direct attention to several considerations. The production of bye-product ammonia at gas-works generally is not uniform throughout the year; the load factor varies appreciably as between winter and summer months. Where a sulphuric acid works is erected primarily to supply gas-works needs, it will be appreciated that it is impossible to operate advantageously where the demand for sulphur acid arises almost exclusively from gas-works.

Apart from this, the sulphuric acid industry in this country is in a peculiarly unfortunate position at the present time. Its percentage production is low, and of the order of about 60 p.ct. No wonder, therefore, that small works regard the prices which are being charged as somewhat high.

At a centrally situated chemical works it will be possible to provide more modern and more efficient sulphuric acid plant than generally exists in the United Kingdom to-day. Such plant can be erected at less capital cost, and this obviously has an important bearing on the price at which sulphuric acid can be manufactured. Moreover, at any such centrally situated chemical works it will be possible to arrange for other fertilizer products to be manufactured from sulphuric acid, in order to maintain a fairly even and high percentage production, so as to ensure the manufacture of sulphuric acid at a minimum of cost.

What the gas companies have failed to do in this matter is to act in a resolute way. With a knowledge of all the circumstances, with an appreciation of the fact that the gas industry can ally itself to another important industry, it would be easily

possible to establish centrally situated chemical works throughout the country to advantage. Such works should be capable of absorbing, or disposing of, to a large extent, the production of ammonium sulphate, or mono-ammonium phosphate, or diammonium phosphate, or calcium nitrate, or double superphosphate, or other compound fertilizer products. After all, the profit on fertilizers is to be found in the sale of compound fertilizers, or their equivalent in the shape of chemical fertilizers. This matter will need to be evolved diplomatically, and with a full knowledge of the technical, economic, and financial considerations involved. It will be equally necessary to consider the strategic points at which such works can profitably be established.

An Inferiority Complex.

It is to be regretted that the gas industry has assumed a sort of inferiority complex in its relation to the synthetic ammonia industry. What the synthetic ammonia industry can do can be achieved equally well, and in some respects perhaps better, by the gas industry.

As regards the interesting observations which have been made about a process of separating ammonium bicarbonate from gas, and the peculiarly fascinating account which has been given by Mr. Wilson, of Burton-on-Trent, on this subject, I would direct attention to the 1926 Applied Chemistry Report, in which the following significant reference was made:

> Large quantities of carbon dioxide abound at most synthetic and other ammonia works, and a carbonate ion is probably available at less cost than the sulphate ion obtained via anhydrite. It would be an advantage to produce ammonium bicarbonate—a very useful fertilizer—if it could be stored and shipped without loss due to its volatility.
>
> Methods have been sought with the object of overcoming these disadvantages. It has been found that high volatility is due to the presence of a small proportion of ammonium carbonate or carbamate, or double or triple salts with bicarbonate.
>
> Pure bicarbonate is only obtained by crystallizing from a hot solution while continuously pumping in carbon dioxide, and not by saturating aqueous ammonia or ammonium carbonate with carbon dioxide while cooling.

Other references have been made to the density and stability of the product, and how these can be increased by the addition of substances which influence the surface tension.

It would be impossible to convert the whole of the bye-product ammonia in this country into ammonium bicarbonate, as no market exists for such a quantity in that form. It may well be, as has already been suggested, that this process might prove economically sound as an ammonia concentration one. Many aspects of the matter, however, need further investigation, particularly the question of the costs of compression, and whether this is really necessary.

Time for Resolute Action.

The bye-product ammonia problem has been discussed sufficiently. It is now time for resolute and determined action, on sound and approved lines. The Ammonia Sub-Committee can, however, continue to discharge a useful duty by keeping in the closest touch with all developments, and in arranging to scrutinize the claims of new processes.

The President: I am sure we have all been very interested in what Mr. Parrish has told us. I must, however, take some little exception to his suggestion that the Institution is not alive to the subject. The mere fact that we have an Ammonia Committee, and that Mr. Parrish is a member of it, is, I think, sufficient indication that the matter has not escaped the attention of the Institution. We have in the report a summary, the last word to be said; and item 4 of the summary says: "Consideration should be given to the organization of district co-operative schemes for the treatment of concentrated liquor." We have had that view expressed by several speakers, and I think it is up to the Ammonia Committee to obtain sufficient knowledge of the situation as it exists in the various parts of the country. That can easily be done by communication and getting into touch with the District Associations. It is largely a question of territory. Wherever any concentration is going to be undertaken it must be undertaken bearing in mind the suitability of the district.

Statement No. 5 in that summary says: "Consideration should be given to the possibility of making the gas industry self-supporting in respect of sulphuric acid." That is a more knotty question, but I do not think anyone can say the Institution has overlooked this subject.

Price for Spent Oxide.

Mr. A. L. Holton: As one who makes sulphuric acid, I want to take the opportunity of calling attention to the remark in the paper by Mr. Hollings and Dr. Smith that "It appears to us that this cost"—*i.e.*, of sulphuric acid—"cannot be considered by the gas industry without reference to the price obtained for the spent oxide." I am a little bit afraid, however, that with the spent oxide one is using on sulphuric acid works there is a danger to-day, because, if you are attempting to get rid of the ammonia and other things, you are not purifying your gas as you ought to, and you are sending products into your oxide which add to the cost of sulphuric acid manufacture, I am sure Mr. Parrish will bear me out in this; and if you want to get a good price for your spent oxide, do not put ingredients into it that should not be there and which will add to the cost of making sulphuric acid.

Dr. Smith's Reply.

Dr. Smith, replying to the discussion, said: The discussion on this subject of ammonia has probably satisfied the Committee in that there has been no serious adverse criticism on the policy they have indicated to you that should be laid down. I believe that Mr. Wilson, in his very lucid and valuable statement this morning, was wrong when he suggested it was practicable to think of putting on the market the equivalent of nearly 200,000 tons of ammonium carbonate per annum, as an alternative method to supplying ammonium sulphate. There is not a market for anything like that quantity, not a fraction of it; and therefore our contention still stands that the value of his process was in forming a means of conveniently handling concentrated ammonia, and this should be gone into very carefully. It is a really valuable addition to the technique and the possibilities of handling concentrated ammonia. I think it will be agreed that the lessons to be drawn from the work of the Ammonia Committee are, first, that we should tighten up efficiency all round, and this cannot be done without the application of the technique of first-class chemical engineering; and, secondly, and probably more important still—and this did not come in the report, but is confirmed by Mr. Parrish—we need to-day to recognize our strength as an industry, our potentialities, our power, and to get together more. Instead of hoping to continue successfully as isolated undertakings each of which hopes to make a good competitive showing with the rest, it is necessary that we should look on ourselves as one industry, and if necessary work together as one industry, economically and financially in some respects.

Tar Schemes.

A beginning was made with tar and the tar schemes, but I personally believe that, if ever a mistake was made, that was a serious mistake, although temporarily it might have been shown to be an asset compared with the really bad conditions that existed. To think, however, that it is ever necessary for an industry of the size of the gas industry, the power of the gas industry, to have to go to other people and split your profit and throw over the responsibility of selling to anyone else is a grave censure which you are applying to your industry; and if it were suggested that this concentration of ammonia should be done in a similar manner, allowing people outside the industry, and uncontrolled by the industry, to concentrate ammonia and work it up into something profitable, I say you would make less profit than you are doing now—and that is saying a lot. You cannot know all the facts; and when you are working with other people who are out to make profits just as you are, it is impossible to satisfy yourselves at every stage, whatever facilities you have, that you are getting a fair deal. It is the last thing in the world that Mr. Hollings and I would have in our minds that there should be co-operative ammonia and sulphuric acid handling. We should have hated to make the suggestion that it was conceivable that ammonia or sulphuric acid would be dealt with in the way you deal with tar.

It is unnecessary to say, in reply to Mr. Madden, that in some cases it might be an advantage to reduce the amount of ammonia. Everyone will agree with Mr. Madden in that contention. Where the ammonia is of a value less than that of sulphuric acid, as stated in our report; but where ammonia is just on the borderline, then obviously the more ammonia you can make the better it is for the undertaking. As has been pointed out, it is the water that is associated with the ammonia that has to be distilled, and not the ammonia. The more water you distil in proportion to the amount of ammonia you make, the worse it is for the costs; and the more ammonia you have as a result of your distillation, the better it is, subject to the ammonium sulphate not having a value less than that of sulphuric acid.

I am very strongly in agreement with what Mr. Parrish has said, and I am glad he has had the pluck and the energy to say it. Of course, I blushed appropriately when he made, accidentally or otherwise, his opening remarks about the consummate value of the report which Mr. Hollings and I have prepared; but there is no intention on our part to suggest that there is anything novel in that report, or that there is anything in it in which we have shown initiative. It is simply a summary of the work of other people; and we, understanding a little about the subject, knew that Mr. Parrish had put these things forward before. But if we had started out to put into the report the name of everybody who had been associated with ammonia, the report would have been a tabulated sheet of names, with nothing else in it. We therefore kept out of the report everything that was unnecessary. Everyone knows that Mr. Parrish and the South Metropolitan Gas Company have made the contributions they have done in the past, and that in 1925 they did anticipate everything that has been put forward in this Report. I am sure Mr. Hollings blushed as much as I did when Mr. Parrish said what he did.

Institution Gas Research Fellowship Report—1929-30

The Influence of the Inorganic Constituents in the Carbonization and Gasification of Coal: The Liberation of Ammonia

By A. H. EASTWOOD, B.Sc. (Institution Gas Research Fellow), and J. W. COBB, C.B.E., B.Sc., F.I.C. (Livesey Professor).

Introductory and General.

The work described in this Report constitutes another stage in an investigation commenced some years ago at Leeds into the liberation of nitrogen and sulphur under varied conditions during the carbonization or gasification of coal.

In the 1921, 1922, 1923, and 1924 Gas Research Fellowship Reports the influences of atmosphere, temperature, and rates of gasification were dealt with. In the present Report we are specially concerned with the effects of the inorganic constituents present in coal on the liberation of nitrogen as ammonia. The results of a parallel study on the liberation of sulphur as sulphuretted hydrogen were published in the Gas Research Fellowship Report for 1928.

A fusible coal (Sharlston Wallsend, Haigh Moor Seam) containing only 1 per cent. of ash was taken, and to it additions of three ash constituents were made. These three, lime, calcium carbonate, and iron oxide, were chosen on the basis of previous work. Each mixture contained 5 per cent. (calculated as oxide) of one of the three compounds, which ensured the dominance of that particular added constituent.

A mixture containing 5 per cent. of crushed pure coke was also investigated with a view to finding what effect the addition of an inert substance would have on the results.

Some work was also done with a sample of the Nottinghamshire coal used by the Gas Investigation Committee in their Studies in Carbonization (18th and 20th Reports). The results are in general agreement with those for the Sharlston Wallsend coal.

The pure coal and the mixtures were carbonized in atmospheres of nitrogen, hydrogen, and a steam-nitrogen mixture containing 60 per cent. of steam. (The pure coal was also treated in a mixture of steam and nitrogen containing 10 per cent. steam.) The total time of carbonization was 9 hours, the temperature being advanced in stages of 100° C. from 200° to 1000° C.

The ammonia was separately collected and estimated at each stage. The cokes when cool were weighed and analyzed, and from the results nitrogen balances were drawn up.

The results may be summarized as follows.

Taking the pure coal; in all cases ammonia evolution commences at 300° C. and reaches a maximum at 700° C. This initial temperature corresponds roughly with that at which the first true decomposition of the ulmin compounds has been held to occur by Wheeler and his collaborators. The maximum at 700° C. is very marked in our experiments, and little ammonia (except in hydrogen) is obtained above it, partly owing to thermal decomposition and partly to the fact that the bulk of the nitrogen which can be obtained as ammonia by the action of heat alone has already been driven off.

In a neutral atmosphere (nitrogen) carbonization up to 1000° C. yields 17 per cent. of the nitrogen of the coal as ammonia.

Substitution of hydrogen for the nitrogen results in an approximately doubled yield, 33·3 per cent. of the nitrogen now being obtained as ammonia. Substantial equivalence exists between the extra ammonia formed and the increase in the quantity of nitrogen lost by the coke. Hydrogen does not reduce the loss of nitrogen in forms other than ammonia.

The use of an atmosphere of steam and nitrogen containing 10 per cent. of steam has little effect on the ammonia yield, although there is a considerable increase in the amount of nitrogen gasified. As this gasification takes place largely at and above 900° C., the nitrogen so liberated appears in the gas in the free state, the ammonia first formed undergoing thermal decomposition.

The use of an atmosphere of steam and nitrogen containing 60 per cent. steam gives a yield of ammonia equivalent to 25 per cent. of the nitrogen of the coal. In this atmosphere the loss of nitrogen from the coke in forms other than ammonia is also increased.

In no case is all the nitrogen of the coal liberated obtained as ammonia, and it would seem that it is impracticable to obtain it all in this form. Thus during the course of this work it was shown that coal on carbonization at 500° C. loses 16 per cent. of its nitrogen, of which only 2 per cent. appears as ammonia, and this at temperatures below those at which extensive thermal decomposition of this compound is likely. The same extensive loss of nitrogen is also shown in the results of Monkhouse and Cobb, given in the 1921 and 1922 Gas Research Fellowship Reports, where cokes prepared at 500° C. are shown to have lost 22 per cent. of the nitrogen of the coal. Although some experiments have been made it has not yet been established in what form this nitrogen escapes. Some undoubtedly finds its way into the tar, but the results of the Gas Investigation Committee show that this quantity is not sufficient to account for anything like the whole loss.

So far as the general effects of the several atmospheres are concerned, the results are in accord with those presented in previous Gas Research Fellowship Reports.

Considering the mode of formation of the ammonia it would seem that this takes place in two ways :—

(1) By the decomposition of some nitrogen compound or compounds, probably mainly ulmic, under the influence of heat. This decomposition commences at 300° C. and gives its maximum yield at 700° C. Hydrogen or steam do not appear to affect it apart from exercising a protective action on the ammonia formed.

(2) By the action of hydrogen on some nitrogen compound in the coke. This reaction does not occur at or below 500° C. The nitrogen gasified in this manner is all liberated as ammonia, although some of this ammonia may be afterwards lost by thermal decomposition. The nitrogen compounds decomposed by this reaction may be present in the original coal, but it is more probable that they are formed during carbonization. They are found to be stable up to 800° C. in a neutral atmosphere (nitrogen).

This second reaction also takes place in steam, the gasification of the carbon by the steam bringing into effective contact with the nitrogen compounds in the coal the hydrogen produced at the same time; the atmosphere being also one favourable to the preservation of the ammonia formed. As this gasification in these experiments takes place largely at and above 900° C., there is a considerable loss by thermal decomposition of the ammonia formed and a corresponding increase in the free nitrogen (*cf.* Pexton and Cobb, Gas Res. Fell. Rpt., 1923, p. 406).

In previous experiments (Gas Res. Fell. Rpt., 1921), when the gasification in steam was carried out over a prolonged period at 800° C., much more ammonia was obtained with no appreciable thermal decomposition.

Effects of Added Inorganic Constituents.

With these mixtures ammonia evolution again commences, in all cases, at 300° C., and reaches a maximum, in all cases except one (iron oxide coal in nitrogen), at 700° C.

In a neutral atmosphere (nitrogen) the addition of lime

or calcium carbonate raises the ammonia obtained up to 1000° C., expressed as a percentage of the nitrogen of the coal, from 17 to 22 per cent., while iron oxide decreases the yield to 15 per cent., there being a marked diminution from 700° C. upwards.

The addition of crushed pure coke shows no effect on the ammonia yield.

In hydrogen the high yield of 33 per cent. obtained from the pure coal is raised to 37 per cent., about the same increase as in nitrogen, by the addition of calcium carbonate. Lime gives a slightly less increase, while iron oxide has no effect, the marked diminution at 700° C. and upwards, noted in the nitrogen atmosphere, not occurring.

In the mixture of 60 per cent. steam and 40 per cent. nitrogen lime raises the yield from 25 to 34 per cent., calcium carbonate to 32 per cent., while iron oxide perhaps raises it slightly, the diminution from 700° C. upwards being again eliminated.

Considering the mechanism of the effects of these inorganic constituents there would seem to be two main actions :—

(1) An action leading to an increased formation of ammonia. The actual yield is greater in all cases up to 600° C., above which much greater importance attaches to—

(2) An action leading to an increased loss of ammonia by thermal decomposition. This naturally increases with temperature.

Further, these added compounds do not affect directly the reaction between hydrogen and the nitrogen compounds in the coke.

When, however, the gasification of fixed carbon by steam is occurring—a limited phenomenon in carbonization—the added inorganic compounds will have an effect on the *rate* of ammonia production because they increase the reactivity of carbon to steam.

Returning to the two actions given above :—

It has been suggested that these constituents affect the nitrogen compounds in the tar, converting some of these into ammonia, but the results of the Gas Investigation Committee suggest that this is improbable.

The present nitrogen balances show that these added compounds decrease the amount of nitrogen left in the coke at 1000° C., as compared with that left in the pure coke. The results of the Gas Investigation Committee indicate, however, that it is possible to obtain an increase in the ammonia yield at the lower temperatures (*i.e.*, below 800° C.) without any corresponding decrease in fixed nitrogen.

With regard to the thermal decomposition of ammonia, it has been shown that below 1200° C. (about) this takes place almost exclusively in contact with various surfaces which act as catalysts, homogeneous reaction throughout the body of the gas being negligible.

Many gases have the power of hindering the reaction by forming films on the surface and so putting it partly out of action.

Hydrogen and more particularly steam are effective in this connection.

Comparing the results with those obtained on a larger scale by the Gas Investigation Committee, it will be seen that there is good general agreement. With the Nottinghamshire coal the only discrepancy is with the results up to 600° C., where the Gas Investigation Committee report decreased yields, a result at present quite inexplicable. Minor differences in the results at other temperatures are presumably due to the very different experimental methods used.

The results of the Gas Investigation Committee also show that the effects produced by these added compounds may vary with the type of coal used, their results with a Durham gas-making coal differing from those with the Nottinghamshire coal.

Prof. COBB : I should like to supplement the presentation of the report which has been made by Mr. Eastwood. It will be in the memory of many of you that at various meetings of the Institution during past years the Gas Research Fellowship Report has been concerned with the liberation of nitrogen from coal and coke as ammonia. The investigators who were principally concerned with that were Dr. Monkhouse and Dr. Pexton, who have now taken up work in other fields. In the work presented at that time we were attempting to get as much information as possible as to what could be liberated in different gaseous atmospheres at different temperatures when time was no object; and in some cases the treatment—as, for example, with hydrogen—would be continued for as much as 100 hours or 200 hours, in order to exhaust, if possible, the reaction occurring at a particular temperature.

When we came to review the action of the inorganic constituents in aiding or otherwise the liberation of ammonia, we had to bear in mind the impossibility of exhausting all kinds of conditions as regards temperature and time; and therefore a system of working was deliberately chosen for the experiments which should reproduce to some extent, as regards temperature and time, the conditions of carbonization. We worked on finely divided coal, raising it in 100° stages and allowing the operation at each stage to continue for one hour, so that altogether the time of carbonization was nine hours. In this way we were able to note the temperature at which the evolution of ammonia was aided or otherwise by the action of the different gases or by the action of the added constituents; and the figures in the Gas Research Fellowship Report show very clearly what these effects were. The first figure is one for the apparatus itself; and it is of a kind with which you have become familiar. The only modification of any consequence in it is on account of the formation of an impenetrable layer on the fusion of the coke; and it was found necessary to introduce a silica capillary as a by-pass through the column of coal that was undergoing carbonization. If you turn to fig. 2, for example, and also fig. 3, there is indicated, especially in fig. 2, the behaviour at each temperature stage. What is plotted is the nitrogen of the coal as ammonia at each temperature stage, the nitrogen of the coal being taken as 100; and this, for pure coal, in fig. 2, brings out quite clearly, to begin with, the very definite position taken by the temperature. The temperature of maximum ammonia evolution is 700° C. This is confirmed by the other figures which you can consult farther on. It is a remarkably constant figure. It is plain also there that the hydrogen is causing a very markedly increased evolution of ammonia. There are also figures given for steam; and I would like to call your attention to these because, if one has regard to the complete combustion of a coal or coke in steam, it is in that way, rather than by heating in any other gas, that the maximum amount of ammonia can be obtained. It might be supposed that steam was influential also to a very great extent in increasing the evolution of ammonia from the coal during the process of carbonization or distillation as opposed to combustion, but it is very evident from these experimental results that, so far as carbonization itself is concerned, steam has very little effect as compared with hydrogen. When the high ammonia results are obtained by steam it is on account of the preliminary combustion of the carbon in steam generating hydrogen and opening up the way to increased ammonia evolution on that account. The steam apparently goes through the intermediate formation of hydrogen, so that in carbonizing it has comparatively little effect, although it has an effect. The diagrams are planned in two ways. In the first place, in fig. 2, for instance, we show what is the rate of evolution of ammonia at each of the 100° stages of temperature. On the other hand, in fig. 3 what is plotted is the total amount of ammonia that has been evolved up to that stage in the experiments; and in reading the paper and noting the phrases that are used in respect of the effects on the yield, it is very advisable that this difference should be borne in mind. The yield up to a certain temperature includes all the ammonia evolved at lower temperatures, and the evolution at the particular temperature. Fig. 3 shows more than double the yield brought about in these experiments by the use of hydrogen and the similar increase due to the use of steam. At the same time a sort of blank experiment was made; a separate experiment with coke in order to eliminate any purely physical effect which arose from the opening-out of the structure by the introduction of an infusible material. The coke was found to have very little effect.

Later on comes the study of the influence of the various oxides, and, as has been shown before, lime has a definite effect in the two coals we studied, by increasing the ammonia yield quite appreciably. On the other hand, oxide of iron, although it probably exercises just the same stimulating effect as regards lower temperatures, begins, as soon as 600° C. is reached, to exercise its destructive effect upon the ammonia, so that, in the case where 5 p.ct. of oxide of iron is added to the coal, you can see by fig. 10 that there is no longer that maximum production of ammonia at 700° C. The maximum production there in the presence of oxide of iron is at 600°; above this the destructive action of the oxide of iron comes into play. The further investigation of these oxides in their effect when we are studying rapid gasification in steam such as may occur in a gas producer, or steam and air, has still to be followed out in detail.

THE BALANCE-SHEET PROBLEM.

Mr. H. D. MADDEN (Cardiff) : In the first place I should like to thank Prof. Cobb and his staff for the work they have done in this research on the ammonia produced from coal. I must confess that two or three years ago I was deeply interested

myself in this work with vertical retorts, using nitrogen to try to increase the quantity of ammonia which can be provided from a ton of coal. At the same time, when I was listening to the debates this morning on the treatment of effluents from sulphate of ammonia and other works, it occurred to me that many of us are faced with a very difficult position, especially those who are not so academic as Prof. Cobb and his staff—I mean those of us who have to present a balance-sheet to our directors. The great trouble we have at the present time is to reduce the quantity of ammonia, rather than to increase it. I have been able to speak to one or two members of the Institution this morning; and with regard to balance-sheets this year the position appears to be most unfavourable from the standpoint of receipts from sulphate of ammonia. I am particularly drawing attention to this aspect of the question, although I know how valuable the work has been which Prof. Cobb and his staff have been carrying out. But I think that for gas engineers who are responsible for balance-sheets there is another question—can we reduce the quantity of ammonia, or can we put that ammonia into another form which will make it more valuable to our balance-sheets than what it is when making it as sulphate and having to use sulphuric acid for the purpose? It is a problem of importance which those who have to present balance-sheets have to bear in mind at this time of the year. That is just the aspect I wanted to put before you, because I should like some information on that side of the question.

Strong Liquor Better than Weak.

Dr. A. Parker: In this valuable Report of the Gas Research Fellowship I am pleased to know that the results of the experiments carried out in the laboratory, raising the temperature in stages of 100° at a time, confirm or agree as nearly as might be expected with the results for nitrogen-ammonia production in tests carried out on a larger scale in the Corbet-Woodall experimental plant described in the 20th Report of the Gas Investigation Committee. I see, however, that there is one point to which attention has been drawn in this present report. In Table III. some figures are given for the yields of ammonium sulphate in the tests described in the 18th and 20th Reports using Nottinghamshire coal. On looking at the table you find in tests 33 and 37 figures for ammonium sulphate in lbs. per ton of coal when carbonizing coal itself, coal mixed with coke, and coal mixed with calcium carbonate and iron oxide, and you notice there that the yields of ammonia were much less when the coal was mixed with calcium carbonate or with iron oxide than with coal alone at 600° or 630° C. It is mentioned in this Report that there seems to be no explanation. These figures were noted when we were doing the work described in the 18th and 20th Reports. The point was noticed at once. The experiments were carefully checked and done in duplicate, and I do not think there is any doubt about the accuracy of them. If we had had time to go on with the work, what we should have done would be to have carbonized up to the particular temperatures in between 500° and 700°, because it strikes me that evidently there is some sudden change over a very small range of temperature. I suggest that it might be worth while to carry out some laboratory experiments between a range of 500° and 700° C. with breaks of 25° or 50° C. instead of 100°.

On the point raised by Mr. Madden I should like to say a word or two. I know you have a lot of trouble with ammonia liquor, and I think the question is this. You want to get rid of ammonia liquor, not ammonia. If you must have ammonia liquor, you might as well have as much ammonia in it as possible, because thereby you reduce the cost of distillation of the liquor per ton of ammonium sulphate produced. I think that is really the position. If you can get rid of the ammonia liquor, so well and good; but if you must have liquor, have it as strong in ammonia as possible.

Elucidation of Coal Constitution.

Dr. Monkhouse: I have been very interested in the results given in this report, and I think it is a stage towards the elucidation of the constitution of coal. Our knowledge of how the nitrogen is linked up in the molecule in coal is very limited. It would appear that there is in coal something of the type of the amino group, which is capable of giving ammonia on distillation. Then there are the compounds capable of liberating ammonia in the presence of hydrogen, and also compounds in which nitrogen is only liberated when you have steam present; and I think some of these results which are very difficult to explain, and which have been referred to by Dr. Parker, may be due to the nitrogen compounds present in the coal. The influence of these various oxides may have some bearing on this particular point. The question is whether these particular bodies are present in the original coal or whether they are the result of carbonization and formation afterwards. This is a matter of conjecture, and the fundamental work being done by Prof. Cobb in this matter may help towards a solution of this problem.

Prof. Cobb's Reply.

Prof. Cobb, replying to the discussion, said: I was not surprised to hear Mr. Madden's criticism. I was perfectly certain that criticism would be forthcoming in connection with this paper, for obvious reasons. As a matter of fact, this forms part of a systematic study which we were carrying out; and I think it was well worth carrying out, even though Mr. Madden suggests that being able to increase the amount of ammonia a little nowadays is not worth very much. This appears to raise a question which Dr. Parker has already mentioned, and which is also raised in the work of the Ammonia Committee, whose report was presented this morning by Mr. Hollings and Dr. Smith. I might call attention to this sentence in this latter report: "It is sometimes erroneously supposed that because the manufacture of sulphate represents a net loss, then it is advantageous to have a low yield of ammonia from the gas-works," and the argument is elaborated. There is no need for me to elaborate it now, however. The other question as to the best form of working up the ammonia, &c., would, I think better be debated in connection with the Ammonia Reports, which are still incomplete. I do not know that anything in our work would bear upon that particular question. As regards Dr. Monkhouse's remarks, I do not think they call for any reply.

The Recovery of Ammonia in Gas Manufacture; Indirect, Semi-Direct, and Direct Processes

By Dr. A. PARKER

[Discussion on the Second Report of the Ammonia Sub-Committee, presented November, 1929—see "JOURNAL" for Nov. 27, Supplement p. 37.]

Dr. A. Parker: This report was presented at the November meeting last year, but there was insufficient time for discussion. There was one contribution at the meeting by Mr. Sensicle, and there was afterwards a written contribution by Dr. Foxwell; and I have replied to these two contributions, the replies having been published in the Technical Press. I think the whole matter was summed up by Mr. Sensicle and Dr. Foxwell, and we are more or less in agreement. The whole subject of ammonia has been considered this morning in the Third Report, and I do not think I need explain the different methods—direct, indirect, and semi-direct—of ammonia recovery. In considering the application of these processes to the gas industry it is largely a matter of cost and quality of the salt, and in the direct and semi-direct processes tar must be more efficiently removed from the hot gas than with the indirect process, and the cost of this must be put on to the cost of the process, unless, for some reason connected with the disposal of effluent liquor, the tar must be removed from the hot gas to improve the quality of the effluent. It should also be remembered in comparing these processes that the indirect process can be run with a stronger liquor than is usual at the present time by avoiding the use of water in the scrubbers, as indicated in the paper by Mr. Hollings and Dr. Pexton.

Electrostatic Methods of Tar Extraction.

Mr. L. H. Sensicle: I made my contribution to this discussion last year, and I have very little to add to what Dr. Parker has said. There is one thing that stands out in connection with the question of semi-direct recovery—that the methods of tar extraction from the hot gas or warm gas are being improved every day. We hear from time to time of the adoption in this country of electrostatic methods of separation. It has been done experimentally at Coventry, and there have been installations on coke oven plants working on a big scale.

The great point I made originally with regard to the direct recovery process was the fact that your effluent liquor was very small in amount and contained oxygen-absorbing constituents which were practically completely phenolic in character; and these are capable of extraction by solvents. Thus it would be unnecessary to use methods of oxidation by bacterial processes of other types of plants that have been described by Dr. Monkhouse. I think eventually we shall find the effluents from this type of plant will be worked up on a profitable basis for the extraction of monohydric phenols.

Mr. P. Parrish: There are one or two words I would like to say on this rather vital subject. I agree almost *in toto* with the view expressed in the report which is before the meeting for consideration. I think the semi-direct and the direct processes stand condemned by reason of the fact that they are incapable of producing ammonium sulphate of the quality that can be produced by the indirect process. I know that in Germany the Association of Coke Oven Managers have been told that unless they improve the quality of their sulphate of ammonia the organization which is responsible for its sale will be compelled to decline to market the product. It is next to impossible in the semi-direct or direct plant to work with a continuous feed of sulphuric acid and that largely arises from the fact that the temperature at which the saturators are operated is of the order of 60° C., and at that temperature the solubility of ammonium sulphate plays a very important part and has a very adverse effect. In order to get over the difficulty of the formation of the rock salt it is found necessary, even where the attempt is made to maintain a continuous feed of acid, to arrest that feed of sulphuric acid and use the acid intermittently in order that the acid content of the bath may be increased, and thereby dissolve the rock salt which has been formed. I know that the curve with regard to acidity varies from 5 p.ct. to 16 p.ct. At 16 p.ct., from investigations which I carried out many years ago, it was found that ammonium bisulphate was formed, and the minuteness of the crystals was such as to render it well-nigh impossible for any successful drying process to be effective; but there are quite a number of other difficulties in connection with the semi-direct and direct processes. Most of the coals carbonized in this country contain salt, and they lead, during the carbonizing process, to the production of ammonium chloride. That ammonium chloride has to be recovered in some form or other. It is either associated with the tar, if one attempts to form virgin liquor, or, if one carries out the semi-direct process, the ammonium chloride is a constituent of the virgin liquor. If an attempt is made to avoid the formation of virgin liquor, then it must be obvious that hydrochloric acid, or probably ammonium chloride dissociated into hydrochloric acid, has to be treated in the mains; and you are face to face with the corrosion problem straight away. But these are only minor aspects. The important trouble with regard to the desirability or otherwise of adopting the direct or semi-direct process lies in the product which is produced. It is impossible to produce anything approaching the standard of sulphate of ammonia which is capable of being produced by the indirect process; and inasmuch as quality will finally play the most vital part in connection with competition between bye-product sulphate of ammonia and synthetic ammonium sulphate, the processes stand condemned by reason of the fact that they produce an inferior quality.

The President: If anybody has experience of the semi-direct or direct processes of ammonia recovery, we shall be very glad to hear from them.

There was no response to this invitation.

Dr. Parker's Reply.

Dr. Parker, replying to the discussion, said: There is not very much in the discussion that I have to reply to, and after all it is only finishing off a discussion which has already been dealt with. Mr. Sensicle, in supplementing his previous contribution, mentioned that the liquor from the direct process—the effluent liquor—was small in quantity. By that I take it he means presumably smaller than with the indirect or semi-direct process. This is so by reason of the steam used in distillation in the indirect and semi-direct processes. Mr. Sensicle also referred to the fact that the effluent from the direct process contains monohydric phenols which might pay for recovery. It is just such factors as this that I had in mind in finishing this report in the tone I did. When the work of the Effluents Committee has proceeded further, then it will be worth while to reconsider the possibility of adopting the semi-direct or direct processes. Mr. Parrish has practically condemned, as far as he is concerned, the semi-direct and direct processes. I do not go so far as Mr. Parrish; I merely put it in this form, that there does not appear to be any decided financial advantage in adopting the direct or semi-direct process over the indirect. In fact, I cannot find very much difference in operating costs unless the tar from the hot gas had to be removed in any case to solve the effluent problem. The question of the salt and the sale of it, I leave to those people who have to sell the salt!

Vote of Thanks

Mr. J. H. Canning said: My task is to propose a vote of thanks to all those who have co-operated with us in making this meeting such a success. In the first place, there is the University of Leeds, which, as you know, has always placed all its resources at our disposal for the purpose of research. Then in the next place comes the Livesey Professor and the Research Chemists, Assistants, and Staff; and I am quite sure that when the expression "Livesey Professor" is used, Prof. Cobb will be the last to object if I mention Prof. Smithells' name in that connection, because we owe him a debt of lasting gratitude. He was the pioneer in all this work and he laid the foundations upon which Prof. Cobb and those helping him have so successfully built up the present edifice of research. The information would not be of much use unless it was embodied in such a way as to be presented to us; and therefore we owe a debt of gratitude to the authors of the reports. In addition, are the gas undertakings and the several gentlemen connected with them who have always very generously placed their works and themselves at the disposal of the various Research Committees. In the next place come the Chairman and members of the General Research Committee and its Sub-Committees, and the Joint Research Committee of the Institution and Leeds University. These Committees have done a very great deal of work. Now I come to the scrutineers. The task of the scrutineers is rather a tedious one, and I think they are entitled to a special vote of thanks, because they perform their work ungrudgingly and well. During the course of the meeting the President paid a tribute to our Secretary; and I am quite sure that all of us will endorse that most heartily. Further, our thanks are also due to the Secretary's staff. In the next place we have to thank the Society of Incorporated Accountants and Auditors, who have placed these palatial premises at our disposal. Finally, I have to propose a very hearty vote of thanks to our Chairman, the President of the Institution. He has presided over our meetings, as usual, with patience and geniality, and I am sure we are very much indebted to him for occupying the chair.

Seconding the vote, Mr. C. S. Shapley, having expressed the hope that the autumnal research meeting will never sink into insignificance, said: I want to say this on my own account, that I am only sorry there is not more research going on at my works. We do not want any vote of thanks from the Institution for it, for the reason that we learn a great deal more at our works from the chemists and the research assistants who come there than is represented by any trouble we may be put to by their presence, or even in preparing plant for them. We feel that our laboratory gains in status because of its association with the Research Chemists of the University, and, incidentally, we are looked up to by the University inasmuch as they feel that they can come on to our works as and when they like without let or hindrance, and can carry out research work at their own free will.

Replying, Prof. Cobb said: I can speak as a representative of the University of Leeds and as a member of its Council, and can assure the Institution that the connection with this great industry as it is existing at the present time between the University of Leeds and the Institution of Gas Engineers is one which is very highly prized. It represents, we believe, an example of co-operation between the University and an industry which has never been exceeded, if it has been equalled, in value and effectiveness. Speaking now as the Livesey Professor, and on behalf of the Research Chemists, Assistants, and Staff, I can again assure you of the great pleasure it has been to us to be of what service we can to the gas industry. Speaking also as an author or part author of some of the reports, I can say that I am quite of the opinion that the reports ought to be in the hands of the printers and distributed in such good time that, for our sake as well as for the sake of the Institution itself, there can be due consideration given to their substance before the discussion comes on. There is a difficulty at both ends, however. The difficulty at one end is that we wish to get into the reports information which is as up-to-date as possible, so that the criticism is not brought forward that we are behind the times. On the other hand comes a difficulty at this end, that by delaying the preparation of the reports to the last minute it involves difficulties on the part of Mr. Alexander and those who have to get the reports printed and circulated in time for the meeting. We have always had the most complete support from Mr. Shapley and his staff at Leeds.

After replying, the President referred "to the very great assistance we received at our meetings from the Press. I think our Press reports, as technical reports, are equalled by none."

GAS MARKETS & MANUFACTURES

Stock Market Report.

[For Stock and Share List, see later page.]

Dull conditions still persisted in most sections of the Stock Exchange last week, and even British Funds, with the exception of 5 p.ct. War Loan, closed on Friday last with fractional losses on the week.

Gas issues, however, were well supported, and inquiries have been put through for several large parcels of stock. No less than fifteen improvements in value were recorded. The list was headed by the East Hull 5 p.ct. maximum stock, to which reference was made in this column three weeks ago, with an increase of 3½ points to 72-75. This price is still on the low side (yielding £6 16s.) compared with other 5 p.ct. maximum stocks quoted in the List—*e.g.*, the Southampton Company's stock at 75-78 yielding £6 10s. 8d., Northampton at 76-81 with a yield of £6 7s. 4d., and Portsmouth at 79-82 (an increase of 2 points this week) yielding £6 4s. 2d. These stocks, which are comparatively small issues and closely held, rarely come into the market, and consequently do not always recover from *ex* div. reductions in price. The Northampton stock is a case in point, having been marked down to its present price when *ex* div. on August 14 last. On the other hand, the Bristol Company's 5 p.ct. maximum stock, a much larger issue, is quoted on the local Exchange at 93½ and yields £5 7s., though the security to the investor varies but little, if at all, in any of these cases.

Other increases to be noted last week were the Tottenham 5½ p.ct. preference, which gained 3 points to 98-101, and improvements of 2 points each were recorded by Alliance and Dublin ordinary to 98-101; South Shields consolidated (at the local Exchange) to 107-109, and South Suburban 5 p.ct. debenture to 99-102. The limits of the South Metropolitan Company's ordinary stock quotation widened to 4 points—viz., 104-108, against the previous 2 points 104-106—and the Company's 6 p.ct. preference stock improved a further 1 point to 112-115.

The result of the recent issue by the York Gas Company of £90,000 5 p.ct. redeemable debenture stock was very satisfactory. Tenders were received for over four times the amount required, and ranged from £102 down to the minimum of £97. The lowest tender to receive allotment was £99 1s. 6d., the average price obtained being £99 6s. 6d.

Coal Markets.

The futility at the present juncture of legislation or any other measures calculated to increase the cost of production of British coal has been fully exposed in the past week by the complete lack of concern of foreign consumers at our threatened troubles. In spite of the possibility of stoppages in many quarters, the markets remained practically dormant, and there was no sign of the usual rush for export coal. There were, perhaps, isolated indications of activity, where home consumers took precautions to fill up stocks, and shipowners bunkered the boats they had in port, but offers were freely circulated from Poland not only to take over Welsh contracts, but to send coals into South Wales. With stocks of 9 million tons lying in Germany, and Polish coal offering at about 2s. below equivalent British qualities, and with Holland, Belgium, France, and even Russia all in the market, the serious position of our export trade is obvious.

South Wales is, in any case, temporarily settled and working. What will interest gas makers more is that Durham is also working. The quotas, at the moment of writing, are not known, but they are hardly likely to reduce output below the present restricted level. It is also rather anticipated that minimum prices will be round about current levels. In the meantime, special Wear qualities are a firm feature, and the quotation has hardened to 15s. 9d. to 16s. f.o.b. Best qualities are likewise firm at 14s. 9d. to 15s., but other sorts are freely offered down to 12s. 6d.

Gas coke is a good feature all round, and the price is maintained at about 21s. 6d.

Current Sales of Gas Products.

The London Market for Tar, Tar Products, and Sulphate.

LONDON, *Dec.* 1.

The values of tar products remain unaltered and are as follows:

Pitch, 47s. 6d. per ton f.o.b.

Creosote, for export, 6d. to 6¼d. per gallon f.o.b.

Pure toluole, about 2s. per gallon; pure benzole, about 1s. 8d. per gallon; 95/160 solvent naphtha, about 1s. 5d. per gallon; and pyridine bases, about 3s. 9d. per gallon.

All prices of spirits are *ex* sellers' works.

Tar Products in the Provinces.

Dec. 1.

The average prices of gas-works products during the week were: Gas-works tar, 20s. to 24s. Pitch—East Coast, 46s. f.o.b. West Coast, Manchester, Liverpool, Clyde, 46s. f.o.b.* Toluole, naked, North, 1s. 6¼d. to 1s. 7¼d. Coal-tar crude naphtha, in bulk, North, 9d. to 10d. Solvent naphtha, naked, North, 1s. 2¼d. to 1s. 2¾d. Heavy naphtha, North, 11d. to 1s. Creosote, in bulk, North, liquid and salty, 3¼d. to 3¾d.; low gravity, 1¼d.; Scotland, 3¼d. to 3¾d. Heavy oils, in bulk, North, 5¼d. to 6d. Carbolic acid, 60's, 1s. 4½d. to 1s. 6d. Naphthalene, £10 to £12. Salts, £3 to £5, bags included. Anthracene, "A" quality, 2½d. per minimum 40 p.ct., purely nominal; "B" quality, unsaleable.

* All prices for pitch are now quoted on the basis of f.o.b. In order to arrive at the f.a.s. value at any port, it will be necessary to deduct the loading costs and the tolls whatever they may be.

Tar Products in Scotland.

GLASGOW, *Nov.* 29.

Trading is on a small scale, and competition is keen for any orders on the market. Makers' quotations are unchanged.

Pitch.—Value is unaltered at 42s. 6d. to 45s. per ton f.o.b. Glasgow for export and 42s. 6d. per ton f.o.r. for home trade.

Refined tar to Ministry of Transport Specification is being inquired for in considerable quantities for next season, and the price is 2¾d. to 3¼d. per gallon f.o.r. naked.

Creosote.—The market has been quieter during the week, but prices are unchanged. B.E.S.A. Specification is 2¾d. to 3¼d. per gallon; low gravity, 3d. to 3¼d. per gallon; and neutral oil, 3d. to 3¼d. per gallon—all in bulk *ex* works.

Cresylic.—Only small orders are being placed. Pale, 97/99 p.ct., is 1s. 6d. to 1s. 7d. per gallon; dark, 97/99 p.ct., 1s. 5d. to 1s. 6d. per gallon; and pale, 99/100 p.ct., 1s. 8d. to 1s. 9d. per gallon—all f.o.r. in buyers' packages.

Crude naphtha.—Value continues steady at 4d. to 4¼d. per gallon in bulk at makers' work.

Solvent naphtha.—Orders are scarce, and prices are easy. 90/160 is 1s. 2¼d. to 1s. 3d. per gallon, and 90/190, 1s. to 1s. 0¾d. per gallon.

Motor benzole.—Distillers are holding for 1s. 4d. to 1s. 4½d. per gallon f.o.r.

Pyridines continue without interest. 90/160 is nominal at 3s. to 3s. 3d. per gallon.

Benzole Prices.

The following are considered to be the market prices at the present time:

	s. d.		s. d.	
Crude benzole	0 7½	to	0 8½	per gallon at works
Motor ,,	1 3	,,	1 4	,, ,, ,,
Pure ,,	1 7½	,,	1 8½	,, ,, ,,

Trade Notes.

New Plant for Barrow Works.

The Barrow-in-Furness Gas-Works, in their new carbonizing extension at Salthouse, are adopting the Dempster-Toogood descension (scrubber) offtake pipes, and also the flat bench-covers (in lieu of the usual main arches), as manufactured by Messrs. Robert Dempster & Sons, Ltd., Elland.

"Hailware" Shades and Globes.

Two new leaflets have been published by Messrs. Hailwood & Ackroyd, Ltd., of Morley, near Leeds, showing a range of etched (*verre gravé*) shades of artistic and modern designs, well glasses, flambeau globes, and metal fittings. A number of attractive table lamps are also shown, which, it is suggested, should prove a very popular line for Christmas trade and presents.

Mercury Switches and Relays.

Messrs. Isenthal & Co., Ltd., of Duncan Works, Victoria Road, North Acton, W. 3, have published a new and complete list of their mercury switches and relays. The advantage of this type of switch, state the makers, are undoubted. The spark takes place in a sealed vessel, and therefore the switch is perfectly safe when used in positions where there may be explosive gases or inflammable material. The contact resistance never varies, whereas metallic contacts exposed to air are subject to change, frequently with serious results. All cleaning of contacts and subsequent re-adjustment is avoided.

Contracts Advertised To-Day.

Gas Oil.

Borough of Bexhill. [Advert. on p. 753.]

Mansfield Gas Committee. [Advert. on p. 753.]

STOCK AND SHARE LIST.

[For Stock Market Report, see earlier pages.]

Issue.	Share.	When ex-Dividend.	Dividends. Prev. Hf. Yr.	Dividends. Last Hf. Yr.	NAME.	Quotations. Nov. 28.	Rise or Fall on Week.	Transact'ns Lowest and Highest Prices During the Week.
£			% p.a.	% p.a.				
171,978	Stk.	Aug. 14	5	5	Aldershot 5 p.c. max. C.	73—78	..	..
522,992	,,	,,	4	4	Do. 4 p.c. Pref.	73—76	..	..
1,551,868	,,	Oct. 9	7½	7½	Alliance & Dublin Ord.	98—101	+2	99⅜—104½
374,000	,,	July 10	4	4	Do. 4 p.c. Deb.	64—67	..	..
522,655	,,	Aug. 28	7	7	Barnet Ord. 7 p.c.	108—111	+1	109
300,000	1	Oct. 13	1/4½	1/7½	Bombay, Ltd.	15/6 17/6	..	16/—16/9
174,500	10	Aug. 14	9	9	Bournemouth 5 p.c.	14½—15½	..	..
500,050	10	,,	7	7	Do. B 7 p.c.	12½—13	..	..
439,160	10	,,	6	6	Do. Pref. 6 p.c.	11—11¼	..	..
50,000	Stk.	June 26	3	3	Do. 3 p.c. Deb.	58—61	..	..
162,025	,,	,,	4	4	Do. 4 p.c. Deb.	77—80	..	..
357,900	,,	Aug. 28	7½	7½	Brighton & Hove 6 p.c. Con.	112—117	..	..
871,880	,,	,,	6½	6½	Do. 5 p.c. Con.	102—105	+1	103½—104½
1,287,500	,,	July 24	5	5	Bristol 5 p.c. max.	93—94*a*	+½	..
855,000	,,	Sept. 25	8	7	British Ord.	108—113	..	112—112½
100,000	,,	June 26	7	7	Do. 7 p.c. Pref.	112—117	..	..
120,000	,,	,,	4	4	Do. 4 p.c. Red. Deb.	75—78	..	76½
450 000	,,	,,	5	5	Do. 5 p.c. Red. Deb.	97—100	..	..
100,000	,,	June 26	5	5	Cambridge 5 p.c. Deb.	97—100	..	..
100,000	10	May 22	6	10	Cape Town, Ltd.	9—10	..	..
100.000	10	Nov. 6	4½	4½	Do. 4½ p.c. Pref.	6½—7½*	..	7—7⅞
150,000	Stk.	June 26	4½	4½	Do. 4½ p.c. Deb.	71—76	..	..
626,860	,,	July 24	6	6	Cardiff Con. Ord.	95—98	..	..
287,860	,,	June 26	7½	7½	Do. 7½ p.c. Red. Deb.	99—102	..	..
157,150	,,	Aug. 14	6½	5	Chester 5 p.c. Ord.	86—91*b*	..	..
98,936	1	Oct. 9	12/-	12/-	Colombo, Ltd. Ord.	32/—34/-	..	33/—33/6
24 500	1	,,	1/4½	1/4½	Do. 7 p.c. Pref.	18/—20/-	..	18/6 - 18/7½
609,204	1	Oct. 9	1/9½	1/4½	Colonial Gas Assn. Ltd. Ord	16/6 -18/6	..	..
296,053	1	,,	1/4½	1/7½	Do. 8 p.c. Pref.	18/—20/-	..	..
2,073,280	Stk.	July 24	7	6	Commercial Ord.	94—97	..	94½—97
475,000	,,	June 26	3	3	Do. 3 p.c. Deb.	58—61	..	..
787,560	,,	Aug. 14	7	7	Croydon sliding scale	105—108	..	107½
453,100	,,	,,	5	5	Do. max. div.	81—84	..	..
542.270	,,	Aug. 14	10	7	Derby Con.	115—125*e*	..	..
55,000	,,	June 26	4	4	Do. Deb.	65—70*e*	..	..
209,000	,,	Aug. 28	5	5	East Hull Ord. 5 p.c.	72—75	+3½	74½
1,002,180	,,	Sept. 25	17*g*	14	European, Ltd.	100—110	..	102—110
18,629,125	,,	July 24	5‡	5‡	Gas Light & Coke 4 p.c. Ord.	19/7½—20/1½*f*	+·/1½	19/6—20/-
2,600,000	,,	,,	3½	3½	Do. 3½ p.c. max.	63½—65½	+½	63—65½
4,157,020	,,	,,	4	4	Do. 4 p.c. Con. Pref.	79—84	.	80½—81½
5,602,620	,,	June 26	3	3	Do. 3 p.c. Con. Deb.	60—63	..	62½—63
3,642,770	,,	,,	5	5	Do. 5 p.c. Red. Deb.	101—104	..	102½
161,480	,,	Sept. 11	10	10	Harrogate Cons. 10 p.c. max.	155—160	..	..
82,500	,,	Aug. 28	7	7	Hastings & St. L. 5 p.c. Conv.	97—102	..	..
258,740	,,	,,	5½	5½	Do. 3½p.c Conv.	77—82	+1	..
70,000	10	Oct. 9	‡	10	Hongkong & China, Ltd.	13—14	..	..
218,200	Stk.	Aug. 14	6	6	Hornsey Con. 3½ p.c.	88—91	..	..
2,436,594	,,	Nov. 6	25	15	Imperial Continental Gas.	340—360*	..	345—352
223,130	,,	Aug. 14	3½	3½	Do. 3½ p.c. Red. Deb.	80—85	..	..
235,242	,,	Aug. 14	8½	8½	Lea Bridge 5 p.c. Ord.	123—128	..	125½—126½
2,145,907	,,	Aug. 14	6	6	Liverpool 5 p.c. Ord.	95½—96½*b*	..	..
600,000	,,	Sept. 25	7	7	Do. 7 p.c. Red. Pref.	99—101*b*	..	..
165,736	,,	Aug. 28	8	9	Maidstone 5 p.c. Cap.	120—125	..	..
63,480	,,	June 26	3	3	Do. 3 p.c. Deb.	55—58	..	..
75,000	5	June 26	†10	†10	Malta & Mediterranean	5½—6	..	..
392,000	—	Oct. 1	5½	5½	Metrop'litan (of Melbourne) 5½ p.c. Red. Deb.	88—91	..	..
675,000	Stk.	Nov. 20	†8	†6	Montevideo, Ltd.	100—110*	..	101—103
2,061,315	,,	July 24	5‡	5	Newcastle & Gateshead Con.	16/3—16/9*d*	..	..
682,856	,,	,,	4	4	Do. 4 p.c. Pref.	72—73*d*	..	..
691,705	,,	June 26	3½	3½	Do. 3½ p.c. Deb.	67½—68½*d*	..	..
169,940	,,	Aug. 28	7½	7½	North Middlesex 6 p.c. Con.	115—120	..	..
396,160	,,	Aug. 14	5	5	Northampton 5 p.c. max.	76—81	..	..
300,000	,,	Nov. 20	7	9	Oriental, Ltd.	104—109*	..	..
60,000	5	13 My., '15	—	—	Ottoman	0—¼	..	..
205,162	Stk.	June 26	8	8	Plym'th & Stonehouse 5 p.c.	110—115	..	..
424,416	,,	Aug. 28	8	8	Portsm'th Con. Stk. 4 p.c. Std	107—112	..	..
241,446	,,	,,	5	5	Do. 5 p.c. max.	79—82	+2	78½
186,000	100	June 2	4	4	Primitiva 4 p.c. Red. Deb.	96—99	..	98½
677,837	Stk.	July 24	4	4	Do. 4 p.c. Red. Deb. 1911	83—86	..	..
371,496	,,	June 26	4	4	Do. 4 p.c. Cons. Deb.	83—86	..	..
150,000	10	Sept. 25	6	6	San Paulo 6 p.c. Pref.	8¼—8¾	..	8⅝
1,736,968	Stk.	Aug. 28	6½	6½	Sheffield Cons.	104—106*e*	..	..
95,000	,,	July 10	4	4	Do. 4 p.c. Deb.	76—78*e*	..	..
90 000	10	June 5	†4	†5	South African	4—6	..	..
6,709,895	Stk.	Aug. 14	7½	5	South Met. Ord.	104—108	+1	104—105
500,000	,,	,,	6	6	Do. 6 p.c. Irred. Pf.	112—115	+1	113½—114½
1,895,445	,,	July 10	3	3	Do. 3 p.c. Deb.	60—63	..	62
734,000	,,	Sept. 11	6½	6½	Do. 6½ p.c. Red. Db.	99—102	..	..
91,500	,,	Aug. 14	8½	8½	South Shields Con.	107—109*d*	+2	..
1,543,795	,,	July 24	6½	6½	South Suburban Ord. 5 p.c.	102—105	..	100½—100⅞
468,837	,,	June 26	5	5	Do. 5 p.c. Deb.	99—102	+2	100—101
647,740	,,	Aug. 28	5	5	Southampton Ord. 5 p.c. max.	75—78	..	..
121,275	,,	June 26	4	4	Do. 4 p.c. Deb.	76—79	..	..
179,014	,,	July 24	8	8	Sutton Ord.	115—120	..	..
94,500	,,	June 26	5	5	Do. 5 p.c. Deb.	96—99	..	..
250,000	,,	Aug. 28	7	7	Swansea 7 p.c. Red. Pref.	98—101	..	102½
200,000	,,	June 26	6½	6½	Do. 6½ p.c. Red. Deb.	102—105	..	..
1,076,490	,,	July 24	6⅝	6⅝	Tottenham District Ord.	104 106	..	104¼—105½
150,000	,,	,,	5½	5½	Do. 5½ p.c. Pref.	98—101	+3	..
199,005	,,	June 26	4	4	Do. 4 p.c. Deb.	77—80	..	..
182,380	10	30 Dec., '12	—	—	Tuscan, Ltd.	2—3	..	..
85,701	Stk.	Sept. 25	6	6	Uxbridge, Maidenhead, & Wycombe 5 p.c.	73—78	..	..
809,094	,,	Aug. 28	7	7	Do. 5 p.c. pref.	95—100	..	..
88,330	,,	,,	5	5	Wandsworth, Wimbledon, and Epsom Cons.	88—93	..	..
1,180,970	,,	July 10	—	7	Do. 5 p.c. Pref.	108—113	..	..
200,000	,,	,,	5	5	Do. 5 p.c. Deb.	93—96	+2	93
488,344	,,	June 26	5	5		99—102	..	100½—102

Quotations at:—*a.*—Bristol. *b.*—Liverpool. *c.*—Nottingham. *d.*—Newcastle. *e.*—Sheffield. *f.*—The quotation is per £1 of Stock. *g.*—Paid on £10 shares. * Ex. div. † Paid free of income-tax. ‡ For year. § Div.=10 p.ct. p.a. less tax and less tax on interim dividend.

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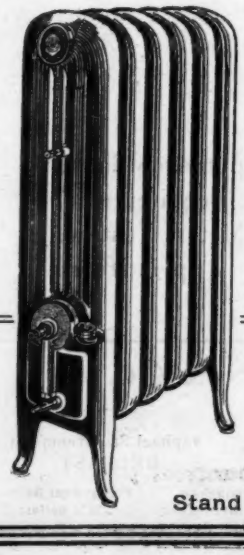

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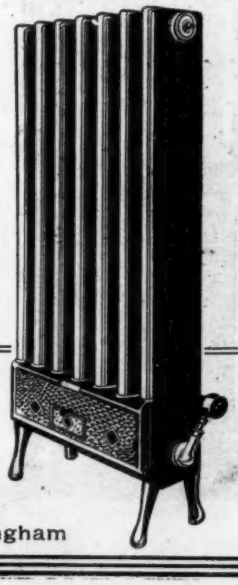

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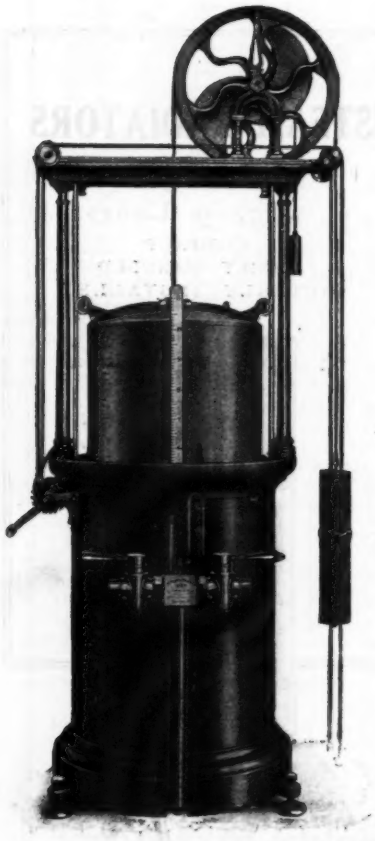

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